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7. SUMMARY AND CONCLUSIONS OF THE OPERABLE UNIT 7-13/14 REMEDIAL INVESTIGATION AND BASELINE RISK ASSESSMENT

This comprehensive remedial investigation and baseline risk assessment (RI/BRA) for Waste Area Group 7 presents estimated cumulative human health and ecological risks associated with the Subsurface Disposal Area (SDA). The SDA is a radioactive waste landfill within the Radioactive Waste Management Complex (RWMC) at the Idaho National Laboratory (INL) Site. Waste Area Group 7 is synonymous with RWMC. Other facilities at RWMC include the Transuranic Storage Area (TSA) and adjacent administration and operations areas. The analysis in this report focuses solely on the SDA. Risk potential associated with the TSA and support facilities will be evaluated in the future after all stored waste is dispositioned and the TSA is closed.

The comprehensive remedial investigation and feasibility study (RI/FS) for Waste Area Group 7 is identified as Operable Unit 7-13/14 in the Federal Facility Agreement and Consent Order (FFA/CO) (DOE-ID 1991). The FFA/CO is a binding agreement between the U.S. Department of Energy (DOE), the Idaho Department of Environmental Quality (DEQ), and the U.S. Environmental Protection Agency (EPA). The FFA/CO provides the framework for Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (42 USC § 9601 et seq., 1980) response actions at the INL Site. Typically, an RI/BRA is founded on site characterization data. Such data include monitoring results that are collected using sampling plans designed to support remedial decisions. Unlike a classical analysis, this RI/BRA depends on predicted concentrations developed through modeling rather than on currently detected concentrations. The DOE, DEQ, and EPA identified this approach as appropriate for the SDA because of the long half-lives of some radionuclides in the SDA and because of issues associated with representative sampling (e.g., sampling heterogeneous media such as fractured basalt and landfill waste). Section 7.1 provides an overview of the RI/BRA, including summaries of site characterization data, modeling results, and risk estimates. Section 7.2 presents conclusions and recommendations relating to development of the Operable Unit 7-13/14 feasibility study.

7.1 Overview

This RI/BRA presents site characterization data, modeling results, and estimates of cumulative human health risk and ecological risk associated with waste buried in the SDA. Evaluating risk is typically an iterative process; each iteration provides an increasingly refined assessment. This RI/BRA is the culmination of a series of risk assessments for Operable Unit 7-13/14, including the Interim Risk Assessment (IRA) (Becker et al. 1998) and the Ancillary Basis for Risk Analysis (ABRA) (Holdren et al. 2002). Improved versions of the same numerical models used in the IRA and ABRA were implemented to predict contaminant concentrations over time in environmental media. These predicted concentrations then were used to estimate risk.

The first four sections of this report present site characterization, comprising remedial investigation elements of this analysis. Sections 5 and 6 develop the baseline risk assessment. Information taken from the IRA and ABRA was updated to reflect additional information developed over the past few years. The regulatory setting for this RI/BRA and the physical setting for the INL Site and the SDA are described in Sections 1 and 2, respectively. Section 3 presents past and current RWMC operations (e.g., waste-generating process knowledge and other historical background information), summaries of various studies and activities, and other information used to assess the site. Section 4 provides a detailed analysis of the nature and extent of contaminants of potential concern in the buried waste and environmental media. Section 5 describes modeling to simulate future concentrations of contaminants of potential concern in environmental media, and Section 6 applies those concentrations to estimate potential human health and ecological risk associated with the SDA. The following subsections summarize each section of this RI/BRA.

7.1.1 Summary of Section 1—Introduction

Section 1 introduces the purpose, scope, schedule, and regulatory background for the Operable Unit 7-13/14 RI/BRA. The purpose of the RI/BRA is to provide DOE, DEQ, and EPA with a basis for future risk management decisions for Waste Area Group 7 under CERCLA (42 USC § 9601 et seq., 1980) and the FFA/CO (DOE-ID 1991). To fulfill that purpose, primary scope elements assess the nature and extent of contamination associated with Waste Area Group 7 and evaluate current and future cumulative and comprehensive risks to identify contaminants of concern. Schedule modifications over time are described, culminating with the current enforceable schedule, which calls for delivering the draft RI/BRA and draft feasibility study in August and December 2006, respectively. The draft RI/BRA was delivered in December 2005, 8 months ahead of the enforceable schedule.

Federal statutes, agreements, and enforceable deadlines govern CERCLA assessments of the INL Site and are the legal basis for remedial decisions. The INL Site was added to the EPA National Priorities List of Superfund sites (54 FR 48184, 1989) under CERCLA. The FFA/CO established the procedural framework for identifying appropriate actions that must be implemented to protect human health and the environment in accordance with the National Oil and Hazardous Substances Pollution Contingency Plan (40 CFR 300), CERCLA, the Resource Conservation and Recovery Act (42 USC § 6901 et seq., 1976), and the Idaho Hazardous Waste Management Act (Idaho Code § 39-4401 et seq., 1983).

The Action Plan attached to the FFA/CO (DOE-ID 1991) includes the original schedule for developing, prioritizing, implementing, and monitoring response actions. The FFA/CO Action Plan provides for remediating RWMC under the designation of Waste Area Group 7. For management purposes, the FFA/CO divided the INL Site into 10 waste area groups. Waste Area Group 7, comprising RWMC, is located in the southwestern quadrant of the INL Site (see Figure 7-1). The FFA/CO Action Plan further divided Waste Area Group 7 into numerous operable units. Overall remediation of the SDA within RWMC is currently being evaluated through a comprehensive CERCLA RI/FS under combined Operable Unit 7-13/14. Ultimately, the RI/FS will lead to risk management decisions and selection of a final comprehensive remedial approach through development of a CERCLA record of decision. Recently, DOE, DEQ, and EPA determined that Waste Area Group 7 should exclude the TSA; therefore, the RI/BRA focuses only on waste buried in the SDA.

7.1.2 Summary of Section 2—Site Background

Section 2 describes important characteristics of the INL Site and RWMC. In addition to location and description, Section 2 summarizes the historical background, provides details of the physical setting (e.g., meteorology, geology, and hydrology), and addresses other important elements (e.g., flora and fauna, demography, land use, and cultural resources).

7.1.2.1 Historical Background. The INL Site, originally established in 1949, is a DOE-managed reservation that historically has been devoted to energy research and related activities. In mid-2003, the laboratory was restructured into two separate business units: one for laboratory research and development missions (i.e., INL) and one for cleanup activities (i.e., Idaho Cleanup Project [ICP]). In February 2005, two separate contractors assumed management of the two business units. This separation allows each organization to focus on its distinct mission: (1) the INL primary mission as the lead laboratory for U.S. nuclear energy research and (2) the ICP mission to remediate the environment and clean up historical contamination at the INL Site as quickly and efficiently as possible (Litus and Shea 2005).

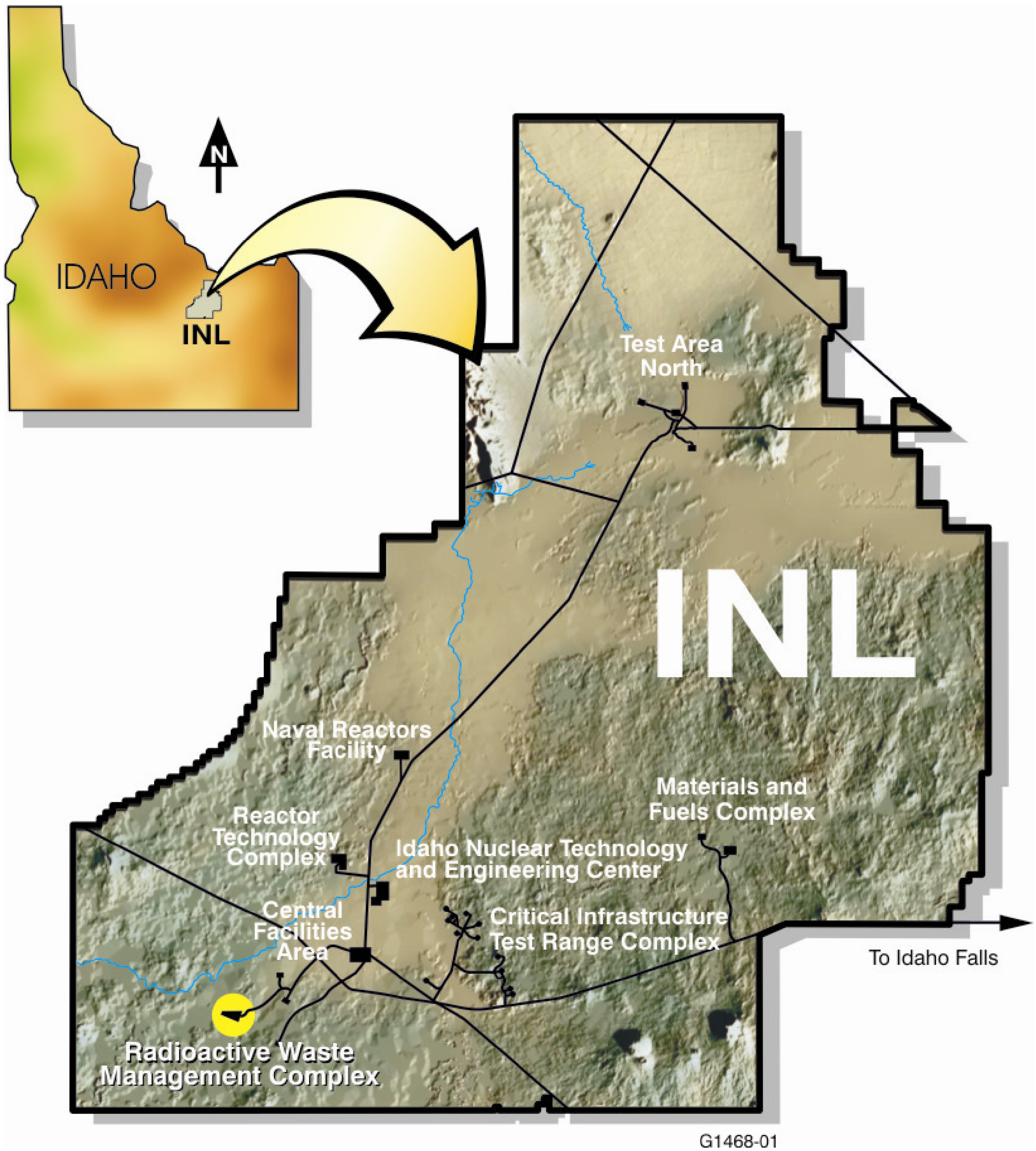


Figure 7-1. Idaho National Laboratory Site.

Four federal government contractors operate facilities at the INL Site. Bechtel Bettis operates the Naval Reactors Facility; Bechtel BWXT Idaho, LLC, manages the Advanced Mixed Waste Treatment Project; CH2M-WG, Idaho, LLC, manages ICP; and Battelle Energy Alliance manages national laboratory functions and operates INL Site services. These contractors conduct various programs at the INL Site under the supervision of two DOE offices: the U.S. Department of Energy Idaho Operations Office and the DOE-Pittsburgh Naval Reactors Office. The U.S. Department of Energy Idaho Operations Office authorizes all government contractors to operate at the INL Site.

7.1.2.2 Physical Setting. The INL Site is located in southeastern Idaho (see Figure 7-1) and occupies 2,305 km^2 (890 mi^2) in the northeastern region of the Snake River Plain. Regionally, the INL Site is nearest to the cities of Idaho Falls and Pocatello and to U.S. Interstate Highways I-15 and I-86. The INL Site extends nearly 63 km (39 mi) from north to south, is about 58 km (36 mi) wide at its broadest southern portion, and occupies parts of five southeastern Idaho counties.

The RWMC covers 72 ha (177 acres) (see Figure 7-2), including the operations and administration area (approximately 9 ha [22 acres]), the SDA (39 ha [97 acres]), and the TSA (23 ha [58 acres]). Burial of radioactive waste in the SDA has resulted from building and operating a wide variety of reactor types at the INL Site and accepting for disposal radioactive and hazardous waste from outside facilities (primarily from the Rocky Flats Plant). Current environmental remediation activities at the INL Site include the following:

- Treating, storing, and disposing of waste
- Removing or deactivating facilities that are no longer of value
- Cleaning up historical contamination that presents risk to human health or the environment
- Preserving cultural resources
- Providing long-term stewardship (Litus and Shea 2005).

Local elevations across RWMC range from a low of 1,517.3 m (4,978 ft) to a high of 1,544.7 m (5,068 ft). Typically, soil in this southern portion of the INL Site is shallow and consists of fine-grained eolian soil deposits with some fluvial gravels and gravelly sand. Occasional pockets of thicker sediment layers form in depressions. Soil in the RWMC area was formed from several types of soil-genesis cycles, including deposition of loess, leaching of calcium carbonate, accumulation of clay, and erosion. The RWMC lies within a natural topographic depression that is associated with the fluvial systems of the Big Lost River and the Big Southern Butte. Some RWMC soil may be derived from historic stream deposits from the Big Lost River; however, evidence of erosion by these systems during the last 10,000 years is not evident.

Undisturbed surficial deposits within the RWMC area range in thickness from 0.6 to 7.0 m (2 to 23 ft) (Anderson, Liszewski, and Ackerman 1996). Irregularities in soil thickness generally reflect the undulating surface of underlying basalt flows. Many physical features are common within the soil stratigraphy of the RWMC area (e.g., pebble layers, freeze-thaw textures, glacial loess deposits, and platy caliche horizons). Surface soil at RWMC has been significantly disturbed and recontoured, and additional backfill—in several cases, sediment from the spreading areas—has been added for subsidence and runoff control. Enclosed by a constructed containment dike, RWMC has been recontoured on many occasions because of disposal and retrieval operations, remedial actions, subsidence mitigation, and surface-drainage modifications.

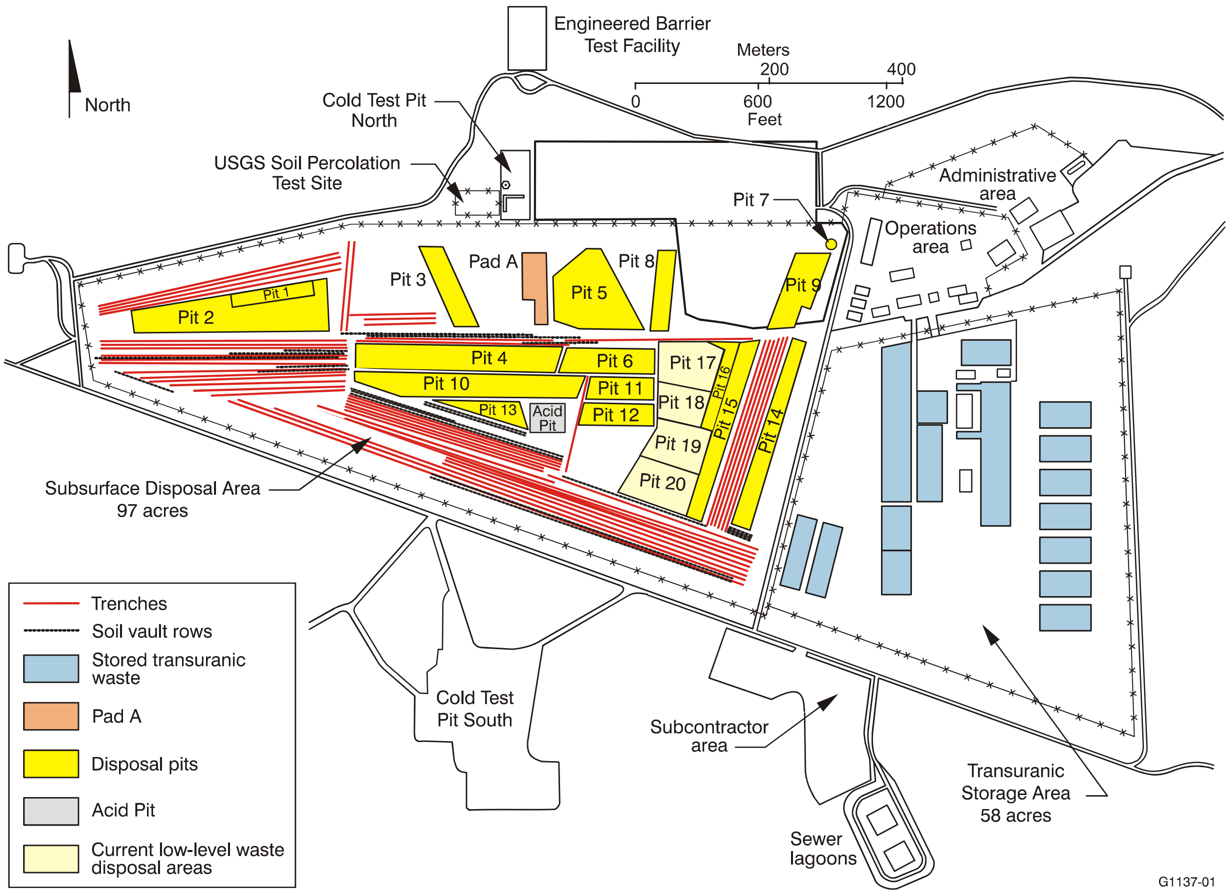


Figure 7-2. Radioactive Waste Management Complex.

The INL Site region is classified as arid to semiarid because of low average rainfall of 22.1 cm/year (8.7 in./year). The RWMC has no permanent surface water features; however, the local depression tends to hold precipitation and to collect additional runoff from surrounding slopes. Surface water from episodes of rain or snowmelt eventually either evaporates or infiltrates into the vadose zone (i.e., unsaturated subsurface) and the underlying aquifer (Holdren et al. 2002). Below the shallow surficial sediment is a thick sequence of basalt flows intercalated with thin sedimentary interbeds. The regional subsurface consists mostly of these layered basalt flows with a few comparatively thin layers of sedimentary interbeds. Interbeds tend to retard downward water migration to the aquifer and are important features in assessing the fate and transport of contaminants. Because subsurface formations are unsaturated most of the year, they are characterized as a vadose zone; however, ephemeral lenses of perched water have been detected in association with interbeds.

The Snake River Plain Aquifer underlies RWMC at an approximate depth of 177 m (580 ft) and flows generally from northeast to southwest. The aquifer is bounded on the north and south by the edge of the Snake River Plain, on the west by surface discharge into the Snake River near Twin Falls, Idaho, and on the northeast by the Yellowstone basin. The aquifer consists of a series of water-saturated basalt layers and sediment. Local perturbations and seemingly anomalous behavior are observed for water levels in the RWMC area. Pump-test results from RWMC area wells show that a region of low permeability is present south and southwest of the RWMC area (Wylie and Hubbell 1994; Wylie 1996).

7.1.2.3 Demography, Flora and Fauna, and Cultural Resources. Populations potentially affected by INL Site or RWMC activities primarily are composed of workers, ranchers, people in neighboring communities, and members of the Shoshone-Bannock Tribes. Approximately 8,000 people currently work at INL Site facilities, though only a fraction of this population visits RWMC (Litus and Shea 2005). Ranchers graze livestock in areas on or near the INL Site; approximately 60% of the INL Site is used for grazing. Residential populations live in neighboring communities comprising the five Idaho counties bordering the INL Site; populations are sparse, ranging from 15 to 62 residents per square mile. No permanent residents live within the boundaries of the INL Site. Members of the Shoshone-Bannock Tribes are allowed access to areas of cultural and religious significance.

Undeveloped land and restricted access to the INL Site provide and protect important habitats for plants and animals. Large numbers of migratory birds of prey and mammals are funneled onto the INL Site because of its location at the mouth of several mountain valleys. The INL Site was designated as a National Environmental Research Park in 1975 (Bowman et al. 1984), and the Sagebrush-Steppe Ecosystem Reserve was created in 1999, comprising 29,947 ha (74,000 acres) of unique habitat in the northwestern portion of the INL Site. Nearly all avian, reptile, and mammalian species found across the INL Site also can be found at RWMC and are supported by various vegetation communities. Larger mammals (e.g., coyotes and antelope) are occasionally seen on facility grounds. No ecologically sensitive areas (i.e., areas of critical habitat) have been identified within RWMC.

All four major types of INL Site cultural resources (i.e., archaeological sites, contemporary Native American cultural resources, historic architectural properties, and paleontological sites) have been identified in the RWMC area. Ten major archaeological survey projects identified an inventory of 13 potentially significant prehistoric sites within a 200-m (656-ft) -wide zone surrounding the fenced perimeter of RWMC and more than 80 additional archaeological resources in the surrounding area. Paleontological remains have been identified in excavations within the facility. Shoshone-Bannock tribal members are consulted about additional resources of Native American concern. In addition, as a result of architectural surveys of 55 buildings administered by DOE within the developed portion of RWMC, three buildings have been identified as potentially eligible for nomination to the National Register of Historic Places.

7.1.2.4 Current and Future Land Use. Land within the INL Site is administered by DOE and is classified by the U.S. Bureau of Land Management as industrial and mixed-use acreage. Approximately 98% of land on the INL Site is open and undeveloped. Large tracts of land are reserved as buffer and safety zones around the boundary of the INL Site, while portions within the central area are reserved for INL Site operations. Remaining land within the reservation core is largely undeveloped and is used for environmental research and to preserve ecological and cultural resources. Grazing and controlled hunting are permitted. The INL Site is crossed by several highways, a rail system, and a high-voltage power distribution loop. Most work takes place within the primary facility areas (Litus and Shea 2005). Future land use (and aquifer use) is expected to remain essentially the same as current use—a research facility within INL Site boundaries, with agriculture and undeveloped land surrounding the INL Site.

7.1.3 Summary of Section 3—Waste Area Group 7 Description and Background

Many studies supplement the Operable Unit 7-13/14 RI/BRA and are incorporated largely by reference. Section 3 contains summaries of several of these studies, which collectively provide important elements of this remedial investigation. Topics addressed include:

- Operational background elements (e.g., analyses of collocated facilities, historical operations, buried waste retrievals, beryllium reflector block grouting, and soil-cover maintenance and repair)

- Descriptions of operable units in Waste Area Group 7 and various investigations and subsequent remedial decisions that were developed

- Source-term assessment to characterize buried waste, based on shipping records, process knowledge, and ancillary analyses

- Contaminant screening for both human health and ecological risk assessments

- Site-characterization activities (e.g., geophysical investigations, probing, actinide mobility studies, analysis of waste and soil retrieved from Pit 9, and focused monitoring of buried beryllium blocks)

- Criticality analysis for buried waste.

7.1.4 Summary of Section 4—Nature and Extent of Contamination

Section 4 evaluates the nature and extent of contamination for all environmental media associated with the SDA. Tens of thousands of samples have been collected near RWMC over the past three decades, and more than 100,000 analyses have been performed. The purpose of this section is to assess monitoring data to identify distributions of contaminants of potential concern associated with the SDA. Monitoring at RWMC has been conducted over time under a variety of programs and with differing objectives. Though locations for monitoring capabilities (e.g., aquifer monitoring wells, vadose zone lysimeters, and waste zone probes) were chosen based on individual program objectives, the common goal of all programs in choosing locations was to maximize the likelihood of detecting contamination. In other words, the monitoring network at RWMC has grown over time and provides data that are not statistically representative of environmental media. Despite the bias toward detection, detections are generally sparse and sporadic, typically near detection levels, and with only a few trends limited to only a few specific locations in the shallow vadose zone. Migration is very limited, with no imminent threat to the aquifer except for carbon tetrachloride, a volatile organic compound (VOC) associated with Rocky Flats Plant weapons-production waste.

To assess the nature and extent of contamination, analytical data associated with contaminants of potential concern at RWMC were compiled and evaluated, encompassing analytical data from 1971 to 2004 and including results obtained by DOE, U.S. Geological Survey (USGS), and various INL Site contractors. Detected concentrations are interpreted by assessing them against comparison values. For concentrations in solid media (i.e., soil, core material, and solids filtered from samples), risk-based concentrations (RBCs) for soil are used. For water (i.e., soil-moisture, perched water, and aquifer samples), maximum contaminant levels (MCLs) established by EPA are used. The RBCs and MCLs provide a scale for interpreting significance of detected concentrations. In addition to soil RBCs and groundwater MCLs, background concentrations for soil and water provide information useful for evaluating constituents that occur naturally in the environment (e.g., nitrate and uranium isotopes) and for estimating detection frequencies.

Data for assessing the nature and extent of contamination for each contaminant of potential concern are organized as follows:

- **Waste zone**—Data sources for the waste zone are historical shipment and disposal records (e.g., constituent inventories, physical characteristics of the waste, and waste packaging) and a limited probe network equipped with vapor ports, lysimeters, and tensiometers in several focus areas.

- **Surface**—Samples of surface soil (typically the top 15 cm [6 in.]), vegetation, and run-off water collected outside of the buried waste, but within the interval of shallow surficial sediments (i.e., the region down to the first basalt interface), provide data for the surface interval.

- **Vadose zone**—Vadose zone samples have been collected from lysimeters and perched water wells up to four times a year since 1997. (The USGS has regularly collected perched water samples from Well USGS-92 since 1972.) Because of small sample volumes, analysis is conducted in accordance with a predetermined analyte priority. Soil-vapor samples also are collected routinely and analyzed primarily for VOCs.

- **Cores**—Cores are obtained when wells are drilled, and samples of interbed sediments are collected and analyzed for contaminant concentrations and physical characteristics.

- **Aquifer**—Samples have been collected from the aquifer by ICP and USGS programs since 1972. In 2004, monitoring frequency was reduced from quarterly to semiannually. Typically, a suite of radionuclides and chemicals are comprehensively analyzed.

Monitoring data indicate that some contaminants of potential concern occur in low concentrations in the vadose zone and aquifer and are likely to be attributable to waste buried in the SDA. Volatile organic compounds, particularly carbon tetrachloride, are the only widespread contaminants in the environment. The following subsections summarize the nature and extent of contamination for these intervals.

7.1.4.1 Waste Zone Data. Focus areas for monitoring within the waste zone were carefully selected to maximize the probability of detecting high concentrations of targeted analytes. More than 300 probes have been installed in the SDA since 1998. Most probing was directed at areas containing waste from the Rocky Flats Plant, though some of the probes targeted waste generated by INL Site operations. Sites for probing were based primarily on historical disposal records. Concentrations detected in these focus areas are high for analytes targeted by the probing, corroborating disposal records, and demonstrating success in choosing locations for waste zone monitoring. The most frequently detected analytes, in order of detection frequency, are VOCs, plutonium isotopes, Am-241, and uranium isotopes.

In general, constituent profiles and ratios confirm successful penetration of waste types targeted in each focus area. For example, organic compounds and radionuclides detected in the Depleted Uranium Focus Area in 2004 were compared to waste-disposal inventories in this area, and good correlation was noted. Analytical indicators (e.g., plutonium isotope activity ratios and ratios of various organic compounds) indicate that areas expected to contain waste from the Rocky Flats Plant are primarily composed of weapons-manufacturing waste.

7.1.4.2 Surface. Hundreds of surface soil, vegetation, and run-off water samples have been collected and analyzed for numerous analytes over the past 10 years. Most constituents at RWMC are measured at concentrations near surficial soil background levels, and none have exceeded soil RBCs. Of the contaminants of potential concern, Pu-239/240 and Am-241 are the most frequently detected in surface soil samples (i.e., within the top 15 cm [6 in.]) inside and outside the SDA, at detection rates of about 22 and 21%, respectively. The high number of Pu-239/240 detections compared to Pu-238 suggests the plutonium is either from weapons-manufacturing waste in the SDA or from fallout. Americium-241 and Pu-239/240 concentrations generally are low; however, presence of these contaminants at detectable levels in the surface environment around the RWMC area emphasizes the importance of following radiological control procedures to minimize cross contamination when drilling and installing new monitoring wells and collecting samples. Surface contamination outside the SDA also substantiates the likely origin of Pu-239/240 detected during aquifer well drilling, installation, and sampling in the early 1970s. Detections in samples of vegetation and run-off water were few, and their contributions to the assessment of Pu-239 concentrations were insignificant.

7.1.4.3 Vadose Zone Soil Moisture and Perched Water. Various radionuclides and chemicals are detected in the vadose zone. Except for VOCs, most constituents are detected only sporadically and have no associated temporal or spatial trends. A few constituents are consistently detected in the vadose zone (see Figure 7-3), exhibit concentration trends, and show evidence of migration. Vadose zone constituents that have been identified as contaminants of potential concern, in order of their detection frequency from highest to lowest, are VOCs, uranium isotopes, nitrate, Tc-99, and C-14. The following subsections summarize these constituents.

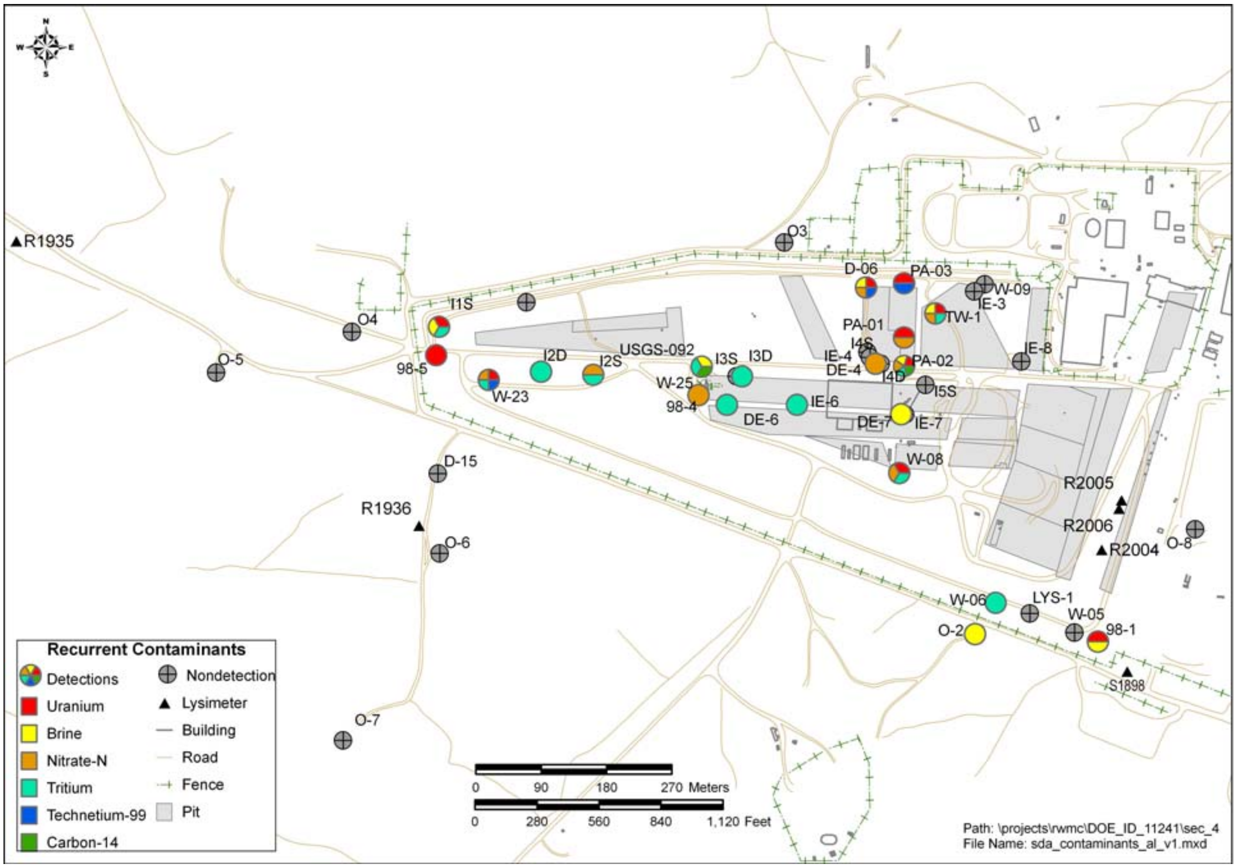


Figure 7-3. Recurring constituents in vadose zone lysimeters.

7.1.4.3.1 Volatile Organic Compounds—Carbon tetrachloride, tetrachloroethylene, and trichloroethylene are consistently detected in perched water and lysimeter samples. Each has been detected above MCLs in perched water samples and in shallow, intermediate, and deep lysimeter samples. Methylene chloride is detected less frequently and at lower concentrations. Methylene chloride has been detected above the MCL in shallow lysimeter and perched water samples, but has not been detected in any intermediate or deep lysimeter samples.

7.1.4.3.2 Uranium Isotopes—Uranium concentrations in all but one location in the vadose zone and aquifer are consistent with naturally occurring uranium. The one exception, TW1:DL04 in Pit 5 near Pad A, exhibits concentrations and isotopic ratios that clearly indicate uranium at this location is anthropogenic and slightly enriched with U-235. This interpretation is further supported by thermal ionization mass spectrometry analysis of a TW1 sample in 1999 (Roback et al. 2000). Concentrations exceeding local background levels are most prevalent in shallow and intermediate depths of the vadose zone near three specific areas in the SDA—around Pad A and Pit 5, the western end of the SDA, and the Acid Pit. Though elevated levels of uranium at these locations are within the range of naturally occurring uranium, other contaminants also are detected in these same locations, indicating some migration may be influencing sample results.

7.1.4.3.3 Nitrate—Nitrate concentrations at many monitoring locations are above the local soil-moisture upper background range; however, because of background variability, only five monitoring locations have concentrations high enough above the upper background range to confidently declare that nitrate is likely from anthropogenic sources (i.e., Wells D15, I2S, W08, W25, and 98-4). The high nitrate concentrations are predominantly found in shallow- and intermediate-depth intervals. Concentration trends are evident at monitoring Lysimeters I2S, PA02, and W25, which are located by Pad A and in the western part of the SDA at depths around 30.5, 2.7, and 4.9 m (100, 9, and 16 ft), respectively (see Figure 7-3). Nitrate measured at Lysimeter PA02 by Pad A appears to be migrating downward because concentrations at Well I4S, about 30.5 m (100 ft) below Pad A, have started increasing.

7.1.4.3.4 Technetium-99—Technetium-99 is consistently detected at depths of 27 m (88 ft) in two locations: Well D06 by Pad A and Well W23 at the western end of the SDA (see Figure 7-3). The concentration associated with Well D06 is increasing. Historically, Tc-99 has not been a priority analyte for vadose zone monitoring; therefore, data are sparse.

7.1.4.3.5 Carbon-14—Carbon-14 concentrations around beryllium blocks are substantially higher than C-14 concentrations near activated steel or other low-level waste disposals. Carbon-14 is detected intermittently in soil-moisture samples (see Figure 7-3), but is readily detected in vapor samples collected near beryllium blocks and activated stainless steel. Carbon-14 also is detected in vapor samples collected from Organic Contamination in the Vadose Zone vapor ports at depths from 11 to 51 m (35 to 166 ft). Collecting samples with suction lysimeters (vacuum) may volatilize the C-14 and produce nondetections or biased-low concentrations. This may explain why C-14 is detected only intermittently in soil-moisture samples.

7.1.4.4 Cores. Few radionuclides are detected in core samples. Most are detected only sporadically and have no associated temporal or spatial trends; however, some radionuclides are consistently detected in RWMC core samples. In order of detection frequency from highest to lowest, these radionuclides are Tc-99, Am-241, Pu-239/240, Sr-90, and Pu-238.

Sample concentrations are generally very low and below soil RBCs used for comparison. Americium-241, Pu-238, and Pu-239/240 were detected primarily in the 0 to 10.7-m (0 to 35-ft) and 11-to 42.7-m (35 to 140-ft) depth intervals, with very few detections deeper than 43 m (140 ft) (i.e., for Tc-99, 10 detections out of 28 analyses; for Am-241, four detections out of 161 analyses; for Pu-239/240, five detections out of 175 analyses; for Sr-90, nine detections out of 158 analyses; for Pu-238, five detections out of 175 analyses). Concentrations of these actinides ranged from 0.002 to 9.6 pCi/g, with a mean concentration around 0.25 pCi/g. Most Am-241 detections were not corroborated with detections of other actinides (e.g., Pu-238 and Pu-239/240), except at monitoring locations in Pit 5, where Pu-238 and Pu-239/240 also were detected. Most valid plutonium and americium detections (i.e., those not taken between 1971 and 1974) are located in the Pit 5 area and the western part of the SDA (see Figure 7-4). All plutonium detections in the 10.7 to 42.7-m (35 to 140-ft) depth interval occurred between 30 and 34 m (98 and 111 ft), which is the location of the B-C interbed. This substantiates the conclusion by Batcheller and Redden (2004) that plutonium (and probably other contaminants) is effectively immobilized in sedimentary interbeds.

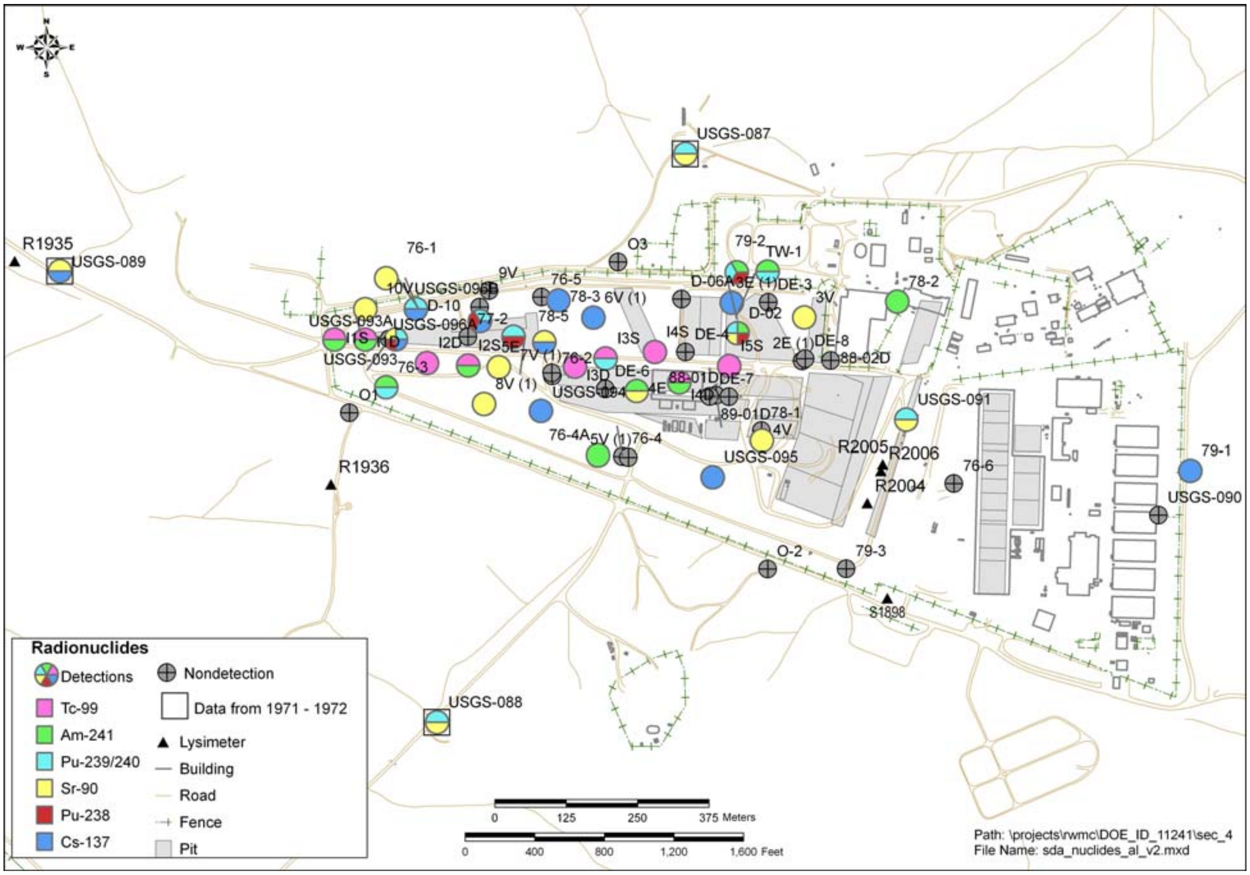


Figure 7-4. Radionuclides detected in core samples between 1971 and 2003.

Detections of Tc-99 in the I-series wells in 1999 were not corroborated by detections in the 2003 core sampling campaign. Some evidence supports the conclusion that Tc-99 is present, while some evidence is to the contrary. However, lysimeter data imply Tc-99 transport may be occurring.

7.1.4.5 Vadose Zone Soil Gas. Volatile organic compounds are consistently detected in soil-gas samples from land surface to the aquifer and as far as 1 km (3,281 ft) beyond the SDA. Thousands of gas samples have been collected from more than 100 permanent soil-gas sampling ports inside and outside the SDA. Compounds are analyzed with an instrument that measures concentrations of the following five compounds, in order of highest to lowest average concentration: carbon tetrachloride, chloroform, trichloroethylene, 1,1,1-trichloroethane, and tetrachloroethylene.

Except for chloroform, these are primary volatile organic constituents in Series 743 sludge received from Rocky Flats Plant. Very little chloroform was buried in the SDA; but because it is a degradation product of carbon tetrachloride, it is ubiquitous in soil gas. Soil-gas samples are not analyzed for methylene chloride and 1,4-dioxane.

Concentrations of VOCs in soil gas have been reduced by the Operable Unit 7-08 vapor vacuum extraction with treatment system that has operated since 1996. Concentrations near active source areas have been impacted less by the remediation system.

7.1.4.6 Aquifer. Very few contaminants of potential concern are regularly detected at levels greater than background concentrations in the aquifer near RWMC. Those frequently detected contaminants of potential concern, in order of detection frequency from highest to lowest, are carbon tetrachloride, trichloroethylene, uranium isotopes, and Cs-137. Other constituents that are not contaminants of potential concern are regularly detected in concentrations greater than aquifer background values. Those other constituents, in order of detection frequency from highest to lowest, are tritium, sulfate, chloride, chromium, and toluene. Figure 7-5 illustrates constituents detected in the aquifer near RWMC.

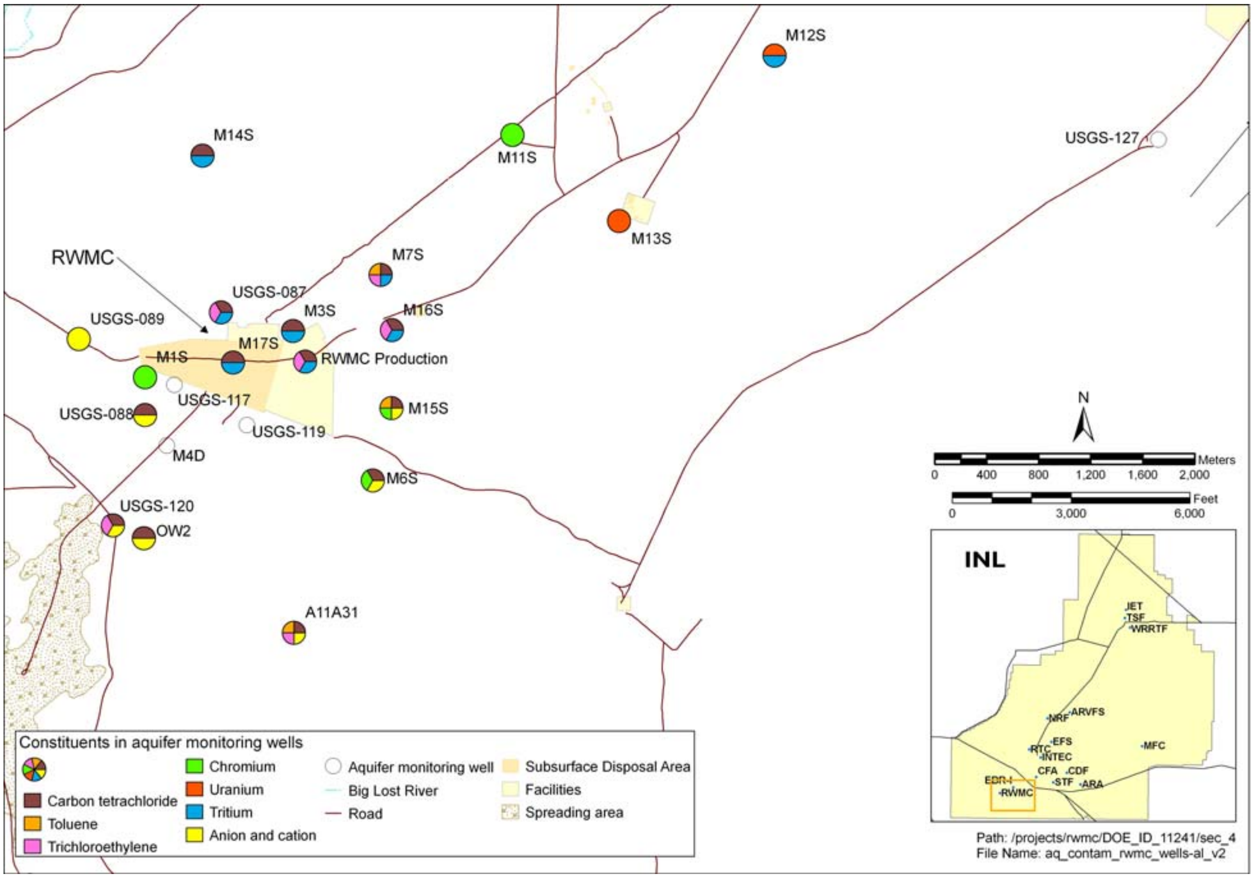


Figure 7-5. Constituents in aquifer monitoring wells.

Some constituents are intermittently detected in the aquifer near RWMC. Those intermittently detected constituents, in order of detection frequency from highest to lowest, are bromide (not a contaminant of potential concern), magnesium (not a contaminant of potential concern), C-14, nitrate, Pu-238, Am-241, Pu-239/240, methylene chloride, and tetrachloroethylene. Detection frequencies are low. For example, Pu-238 plus Pu-239/240 are detected at a rate of 1.0%, which is slightly lower than the detection rate of blank samples (1.2%) and is also the number of times a result is expected to occur outside the 99.7% confidence interval (i.e., a false positive detection).

The only contaminant of potential concern that exceeds its MCL is carbon tetrachloride, which is consistently detected in numerous aquifer monitoring wells at concentrations near and occasionally greater than the MCL of 5 μg/L. Toluene and trichloroethylene also are detected frequently at certain locations in the aquifer beneath the SDA, but concentrations are significantly less than MCLs, and concentration trends are not evident. Low levels of tritium, chromium, and nitrate, as well as a few anions and cations, are detected consistently above background levels in the aquifer beneath RWMC; however, the source of these constituents is uncertain. Possible sources could be transport from the SDA, contributions from upgradient facilities, or corroding well construction material.

Analytical evidence shows intermittently detected contaminants (i.e., C-14, nitrate, Pu-238, Am-241, Pu-239/240, methylene chloride, and tetrachloroethylene) are not widespread in the aquifer near RWMC, and they are not migrating at measurable concentrations. Nitrate concentrations in monitoring Well M6S are higher than all other RWMC aquifer monitoring wells; however, the long-term trend appears to have leveled off at concentrations near the upper background range.

Segregation in the aquifer is observed around RWMC. Tritium is detected only in monitoring wells north of RWMC; high anions and cations (i.e., chlorine, bromine, sulfate, magnesium, and nitrate) are found in wells south of RWMC. Trichloroethylene and toluene are located to the east and south, and high chromium concentrations are isolated to the low-permeability zone beneath the southern RWMC boundary. Excluding VOCs, upgradient concentrations are attributable to other facilities (see Section 2.3.4).

7.1.4.6.1 Carbon Tetrachloride—Low levels of carbon tetrachloride are consistently detected in aquifer monitoring wells in and around RWMC (see Figure 7-5). The maximum concentration was 8 μg/L measured in Well M7S. Concentration trends of carbon tetrachloride in many RWMC aquifer monitoring wells appear to be stabilizing and perhaps declining slightly; however, concentrations in Wells M7S, M16S, RWMC Production Well, and A11A31 continue to fluctuate slightly above and below the MCL of 5 μg/L. No wells exhibited an obvious increasing trend over the past few years, but Well USGS-120 has shown a decreasing trend.

7.1.4.6.2 Trichloroethylene—Trichloroethylene is routinely detected at low levels in aquifer monitoring wells in and around RWMC (see Figure 7-5). The maximum concentration was 3.9 μg/L measured in Well USGS-90 in 1988. Since 2000, the highest concentrations measured were 3.3, 3.2, and 3.0 μg/L in Wells RWMC Production, A11A31, and M7S, respectively. Concentration trends of trichloroethylene in most RWMC aquifer monitoring wells are stable. Trichloroethylene has not been detected in the aquifer above the MCL of 5 μg/L.

7.1.4.6.3 Uranium Isotopes—Concentrations of uranium detected in aquifer monitoring wells are consistent with natural background values and have never approached or exceeded the MCL for total uranium. The number of detections of U-233/234 and U-238 exceeding the upper background comparison concentrations is consistent with expected rates (i.e., less than or equal to 1%). The detection rate for U-235/236, which is slightly higher than those for U-233/234 and U-238, is attributed to (1) relatively high measurement uncertainties associated with low-level U-235/236 analyses and (2) a low upper background comparison concentration at RWMC (ranges at other aquifer monitoring locations around the INL are typically a factor of two higher than at RWMC).

7.1.4.6.4 Cesium-137—The detection rate of Cs-137 for aquifer samples is also very low (i.e., 1.5%), but slightly higher than the expected rate. Many detections contributing to the rate occurred in the early 1970s and are artifacts of well drilling and sampling methods employed at the time. The MCL was exceeded in one aquifer sample collected in 1995; however, Cs-137 has not been detected at that sampling location in subsequent sampling events.

7.1.4.7 Ecological Contaminants of Potential Concern. Ecological risk assessments conducted at the INL Site are based on evaluation and interpretation of the nature and extent of contamination conducted for human health (Van Horn, Hampton, and Morris 1995). Samples have not been collected and analyzed to specifically address RWMC ecological receptors, and sampling data collected as part of the human health assessment were not analyzed in terms of nature and extent for individual ecological receptors (e.g., compared to ecologically based screening levels). However, results of INL Site biotic sampling conducted as part of INL Site environmental monitoring programs were used to assess transport of contaminants from subsurface to surface soil, to locations outside the SDA, and into the food web.

7.1.4.8 Nature and Extent of Contamination—Conclusions. Evaluation of the nature and extent of contamination concludes that low concentrations of carbon tetrachloride are affecting the aquifer near the SDA. Carbon tetrachloride has been detected slightly above the MCL, but concentrations appear to be leveling off, which may be the result of vapor vacuum extraction by the Organic Contamination in the Vadose Zone Project (i.e., Operable Unit 7-08).

Several other contaminants buried in the SDA have been detected at low concentrations in the vadose zone and may be migrating. Most vadose zone detections are in the interval above the B-C interbed. Highest densities were detected in the vadose zone beneath Pit 5 and Pad A and in the western end of the SDA. The most frequently detected contaminants in the vadose zone are VOCs, uranium isotopes, nitrate, Tc-99, and C-14. In addition, Sr-90, Cl-36, Pu-238, Am-241, I-129, and Pu-239/240 have been detected sporadically at concentrations near detection limits.

The monitoring network has been greatly expanded since 1998, with the addition of more than 300 probes in the waste, 62 vadose zone lysimeters, five upgradient aquifer wells, and an aquifer monitoring well inside the SDA. Additional vapor ports also have been installed, bringing the total to 212, 174 of which are sampled routinely. Concentrations in the environment around the SDA will continue to change over time due to several factors. Examples include:

- Remedial actions at the SDA could affect concentrations in the environment (e.g., beryllium block grouting will reduce C-14 concentrations in the vadose zone)

- Continued operation of the Operable Unit 7-08 vapor vacuum extraction and treatment system removes VOCs from the vadose zone

- Subsidence repairs and surface contouring reduce migration by decreasing the amount of infiltration through the waste and into the subsurface

- Degradation of waste packages also influences measured concentrations (e.g., as containers fail over time, more contamination is available for transport to the surface by plants and animals or into the subsurface with infiltration).

7.1.5 Summary of Section 5—Contaminant Fate and Transport

Section 5 addresses modeling of contaminant source release, potential routes of contaminant migration and persistence for the subsurface pathway, and methodology for determining rate constants used in the biotic model. Complete exposure pathways defined by the conceptual site model led to three types of models: source release, subsurface transport, and biotic transport. Persistence of contaminants in the environment was evaluated based on contaminant mobility controlled by dissolved-phase transport, vapor-phase transport, and biotic transport by animals and plants intruding into the waste.

Modeling presented in Section 5 uses best-estimate inventories as the basis for analyzing baseline risk in Section 6. These models also will be used to support remedial decisions for Operable Unit 7-13/14 by simulating long-term effectiveness of various remedial actions. Many aspects of the source-release and groundwater pathway modeling have been improved compared to the ABRA model. However, uncertainties are and always will be associated with predicting movement of contaminants; therefore, conservatism is retained in the modeling and is demonstrated through comparison to monitoring. The primary improvement over the ABRA model is incorporation of additional information into the source-release model regarding inventory, waste streams, and disposal locations within the SDA. These improvements and results from additional characterization have been incorporated into the source-release model and its interface with the vadose zone model. Improvements also have been made in groundwater pathway modeling; however, those improvements have had less impact on predicted concentrations. For groundwater pathway modeling, the primary improvements were updating the VOC modeling and including gaseous-phase C-14 transport.

Eighteen source areas were defined for implementation in the source-release model (see Figure 7-6). The source-term model simulated release of contaminants into the subsurface from buried waste. The DUST-MS code (Sullivan 1992) was used to simulate release of contaminants of potential concern and their long-lived decay-chain products. Simulated mass-release mechanisms comprised surface washoff, diffusion, and dissolution. Release mechanisms were identified based on waste-stream-specific data. Output from the source-release model provided input to both the biotic-transport and subsurface-transport models.

Fate and transport of both dissolved-phase and vapor-phase contaminants in the SDA subsurface were modeled with the three-dimensional TETRAD simulator (Shook 1995). Beginning with contaminant fluxes received as input from the source-release model, the TETRAD model simulates movement of contaminants in the vadose zone down to the aquifer and subsequent aquifer transport. Figure 7-7 shows three-dimensional views of the vadose zone base grid and the first- and second-level grid refinements. Simulations produced estimates of future contaminant concentrations in groundwater. The model was parameterized in consultation with modeling staff from DEQ and EPA, as reflected in values presented in the Second Addendum to the Work Plan (Holdren and Broomfield 2004). Site-specific data describing lithology, spatially variable infiltration, sorption, and other characteristics were applied, where available. Contaminant transport in the aquifer was simulated until peak aquifer concentrations were achieved or to a maximum of 10,000 years. Sensitivity cases were modeled to evaluate effects of upper-bound inventories and additional selected parameters on estimated media concentrations and risk.

The DOSTOMAN code was used to estimate surface soil concentrations produced by biotic transport of contaminants to the surface by plants and animals. Rate constants and other input parameters used in the code (e.g., rooting depths) were selected from current literature, giving preference to site-specific values for the SDA and the INL Site, when available. The biotic model was not calibrated because surface soil at the SDA is routinely redistributed through contouring and operations and because of the fundamental assumption that remedial action at the SDA will include a surface barrier (Holdren and Broomfield 2004). The DOSTOMAN model soil concentrations were estimated for the current timeframe and for future human health and ecological exposure scenarios.

Sensitivity simulations showed that source inventory and the type of mass-release mechanism (i.e., surface washoff, diffusion, and dissolution) have the largest impact on predicted contaminant concentrations in environmental media. The amount of infiltration through the waste and the low-permeability region in the aquifer are two other model features that significantly affect predicted groundwater concentrations. The amount of water that contacts waste influences groundwater pathway concentrations. Water is the driving force that moves aqueous-phase contaminants along the groundwater pathway. Sensitivity simulations show that additional water in the vadose zone, which does not contact waste, primarily dilutes groundwater pathway concentrations. The low-permeability region in the aquifer also substantially impacts predicted concentrations by reducing dilution that would otherwise occur, thus

Figure 7-6. Eighteen source areas simulated in the source-release model.

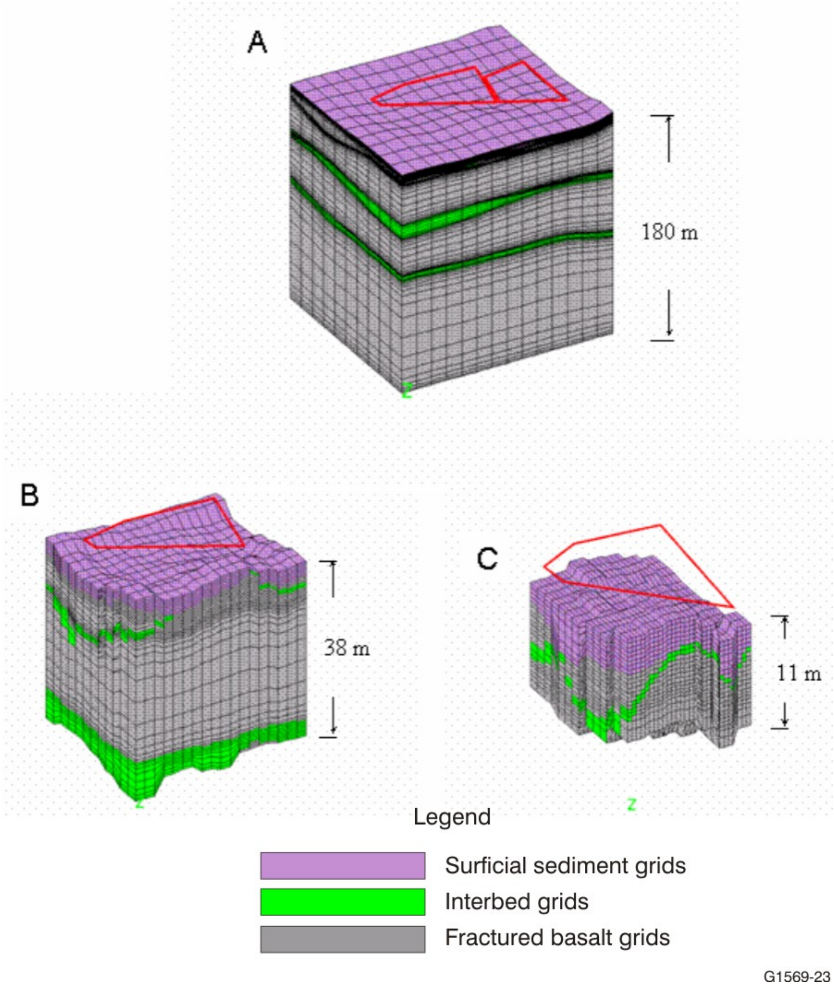
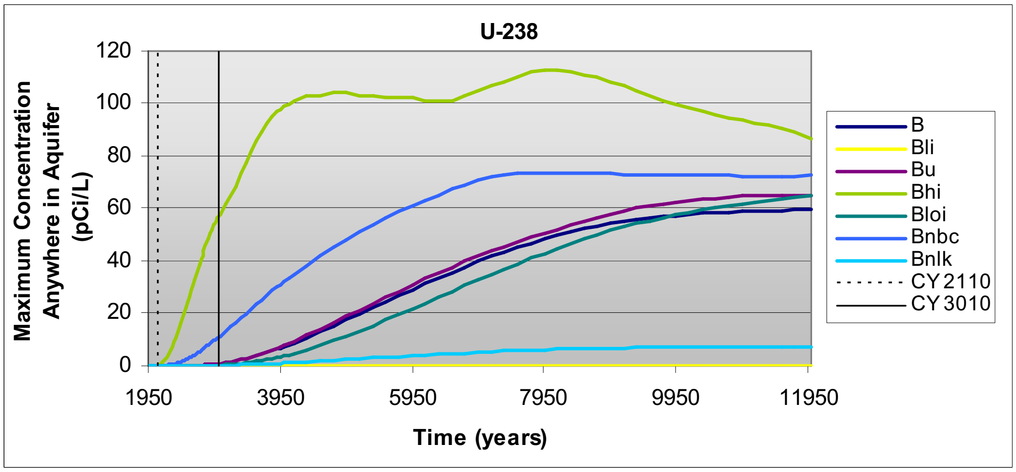
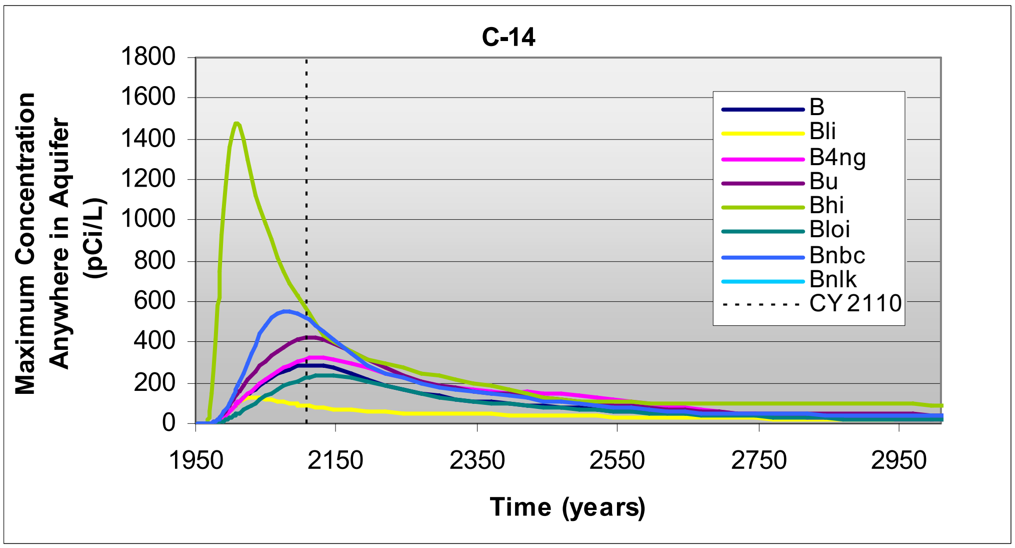


Figure 7-7. Southwest views of base grid (A), first-level refined grid (B), and second-level refined grid (C) beneath the Subsurface Disposal Area showing vertical conformable gridding. The A-B interbed appears black in the base grid as a result of fine vertical discretization.

preserving higher concentrations that reflect concentrations influxing from the vadose zone. Figure 7-8 compares results from various sensitivity simulations for U-238 (a long-lived actinide), C-14 (a dual-phase radionuclide), and nitrate (a dissolved-phase nonradionuclide). Maximum concentrations anywhere in the aquifer are presented to facilitate comparison between various sensitivity simulations. The different simulations are identified using the following nomenclature:

- B = Baseline risk assessment
- Bli = Baseline risk assessment with low infiltration inside the SDA
- B4ng = Baseline risk assessment with no retrieval and no beryllium block grouting
- Bu = Baseline risk assessment with upper-bound inventory
- Bhi = Baseline risk assessment with high infiltration inside the SDA
- Bloi = Baseline risk assessment with low background infiltration outside the SDA
- Bnbc = Baseline risk assessment with no B-C interbed
- Bnlk = Baseline risk assessment with no low-permeability region.





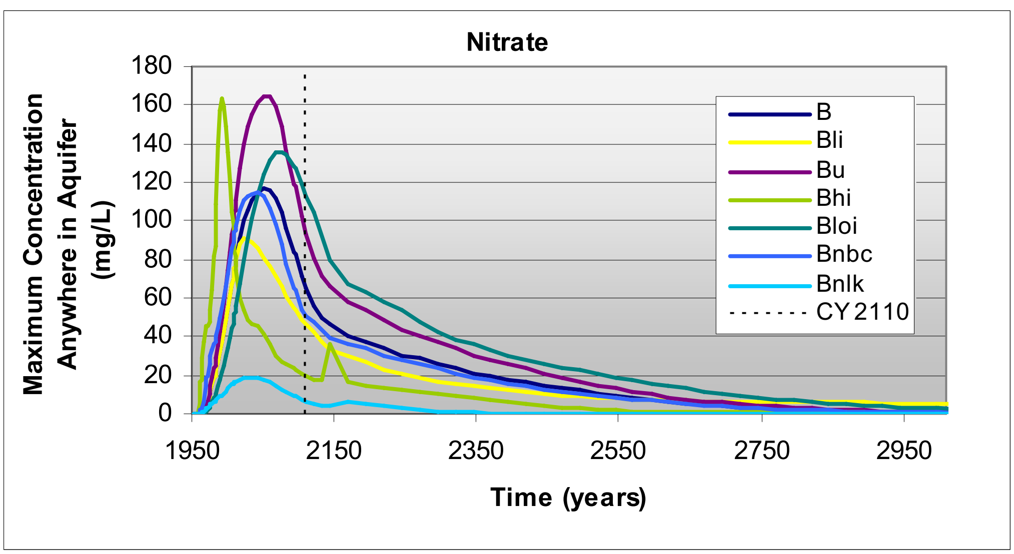


Figure 7-8. Combined sensitivity results for maximum simulated concentration anywhere in the aquifer for uranium-238, carbon-14, and nitrate.

Best judgment was used to select parameters for the source-release model and the subsurface flow and transport model. Fortunately, from an environmental consequence perspective, movement of contaminants in the vadose zone and aquifer beneath the SDA is slow, and no extensive dissolved-phase contaminant plume is available against which to calibrate. An extensive database exists for contaminants in the waste zone, unsaturated zone, perched groundwater (when and where present), and regional aquifer, but there is no clear general pattern of contaminant detections nor trends in concentrations at this time, except for the volatile contaminants. Results of source-release and dissolved-phase subsurface flow and transport models can be compared only to the presence or absence of contaminants in field monitoring data instead of calibration to a contaminant plume. The ongoing monitoring program and evaluation of monitoring results are time consuming and expensive. Results of these monitoring activities have shown promise in identifying trends in contaminant behavior that are useful for determining the relative conservatism in modeling.

Limited calibration to vapor-phase carbon tetrachloride was achieved. Particular parameters were adjusted within reasonable uncertainty ranges until model results adequately agreed with observations of carbon tetrachloride in vadose zone soil-gas and aqueous concentrations in the aquifer. The goal of calibration was to match observed general trends and not be overly concerned with matching values at specific points. This goal was achieved. Limited calibration also was achieved in representing spatial distribution of observed soil-water matric potentials in the B-C and C-D interbeds, where wetter conditions are consistently observed within SDA boundaries compared to locations outside the SDA fence.

Personnel from DOE, DEQ, and EPA consider model results a reasonable basis for estimating potential risk to human health and the environment and for assessing appropriate remedial alternatives to mitigate unacceptable risk. However, results must be considered in light of uncertainties associated with this analysis. Modeling results (i.e., simulated concentrations) are consistently overpredicted in the aquifer (i.e., neglecting sporadic detections), overpredicted at some vadose zone monitoring locations, and underpredicted at other vadose zone monitoring locations. In general, groundwater pathway modeling results are conservative. This conservatism primarily results from (1) overestimating contaminant source release, (2) including rapid vertical transport in the fractured basalt portions of the vadose zone, and (3) including the extensive low-permeability region in the aquifer domain, which limits dilution. Because the model overpredicts current concentrations in the aquifer, it is certain that model results are conservative at present. The amount of uncertainty in the predictive results undoubtedly increases with time, decreasing the level of confidence that the model remains reasonably conservative over time. Monitoring over time and comparing monitoring results against model predictions will be an important aspect of post-record of decision monitoring.

7.1.6 Summary of Section 6—Baseline Risk Assessment

Human health and ecological risk assessments in Section 6 are based on simulated concentrations of contaminants in environmental media developed through numerical modeling (see Section 7.1.5). Potential threats to human health and the environment, in the absence of any remedial action, are evaluated. The following subsections provide a synopsis of general approaches and results of human health and ecological risk assessments.

7.1.6.1 Human Health Baseline Risk Assessment. Building on earlier results in the IRA and the ABRA, Section 6 addresses potential risk to human health from contaminants buried in the SDA. Based on EPA and INL guidance (EPA 1988, 1989; Burns 1995), Waste Area Group 7 was comprehensively assessed by evaluating cumulative, simultaneous risk for all complete exposure pathways for all contaminants of potential concern. The risk assessment included exposure and toxicity assessments, risk characterization, parametric sensitivity analysis, and qualitative evaluation of uncertainty. Contaminant screening for the RI/BRA identified 33 human health contaminants of potential concern for quantitative evaluation: 27 radionuclides, five VOCs, and one inorganic chemical. Risk estimates were developed for occupational and residential scenarios for complete exposure pathways identified in the conceptual site model (see Figure 7-9).

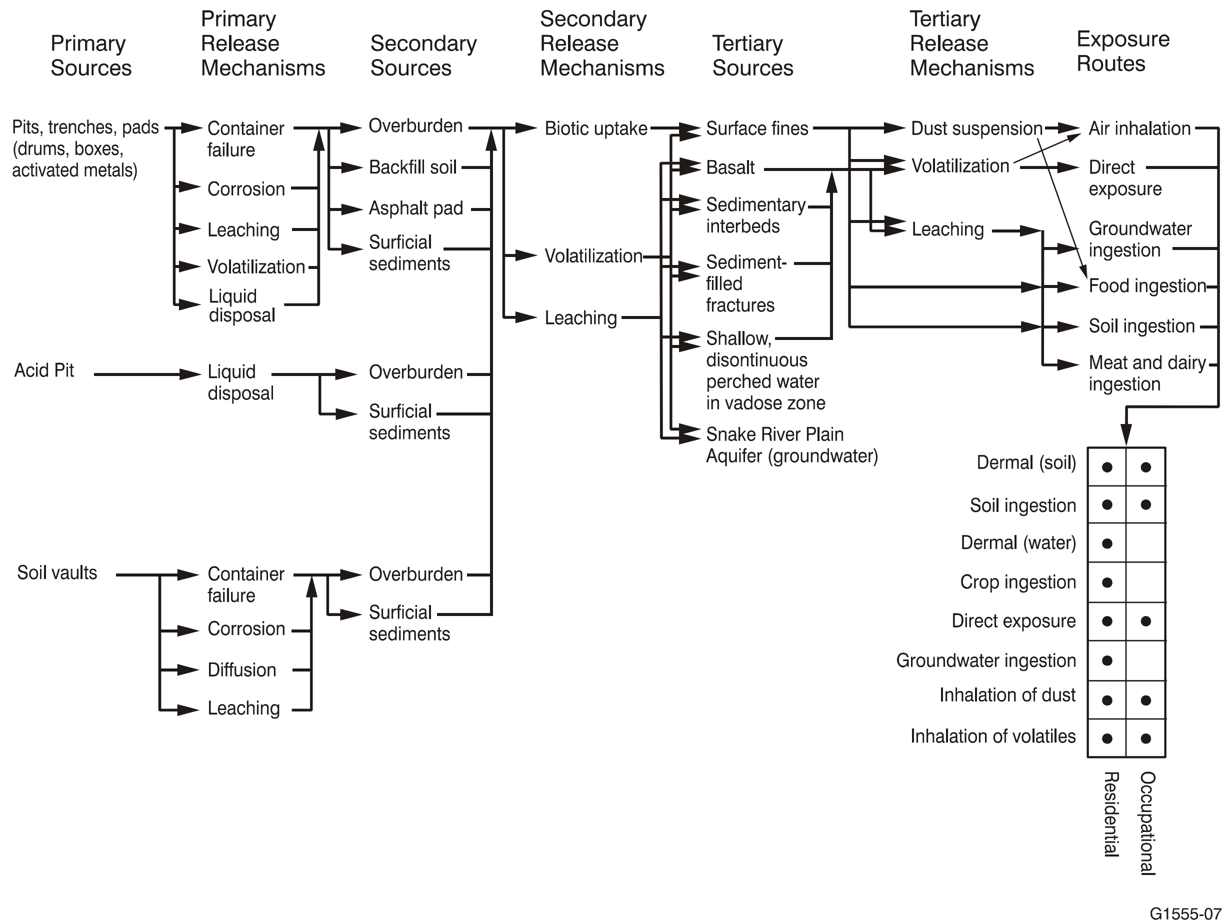


Figure 7-9. Human health conceptual site model.

7.1.6.1.1 Occupational Scenarios—Evaluation of a current occupational scenario yielded risk estimates exceeding 1E-06; therefore, future occupational risks also were assessed as required in the Second Addendum (Holdren and Broomfield 2004). Risk estimates exceed 1E-06 for Sr-90 and carbon tetrachloride for the current occupational scenario. However, risk reaches maximum values for both contaminants within the 100-year current occupational scenario timeframe; therefore, though the future occupational scenario was assessed, results do not add important conclusions to risk characterization.

7.1.6.1.2 Residential Scenarios—For the current residential scenario, groundwater ingestion risk at the nearest downgradient INL Site boundary was assessed. Surface exposure pathways were not examined for a current residential exposure because residential development near RWMC is prohibited by site access restrictions. Cumulative risk for the current residential scenario is approximately 1E-06.

Future residential exposures were simulated, beginning in the year 2110, following an assumed 100-year institutional control period. Future residential analysis reflects land-use projections and the assumption that institutional controls would preclude direct access into the waste, but that a location immediately adjacent to RWMC could be inhabited. The future residential scenario bounds the risk, meaning that risk estimates are higher than for all other exposure scenarios. Concentrations and risks were simulated out to 1,000 years for all pathways except groundwater ingestion. Groundwater risks were simulated until concentrations peaked or to a maximum of 10,000 years.

For residential scenarios, 18 contaminants within the 1,000-year simulation period have cumulative risk greater than or equal to 1E-05, a hazard index greater than or equal to 1, or simulated groundwater concentrations that exceed MCLs. Residential risk estimates are greater than or equal to 1E-05, or simulated groundwater concentrations are greater than MCLs for eight additional contaminants within the 10,000-year simulation period.

In the 1,000-year simulation period, highest residential risks are driven by biotic uptake and surface pathway exposure from Am-241, Cs-137, Pb-210, Pu-239, Pu-240, Ra-226, Ra-228, Sr-90, Th-228, and trichloroethylene. Risks from I-129, 1,4-dioxane, and nitrate are primarily through groundwater pathway exposures; risks from C-14 and carbon tetrachloride are primarily through groundwater and vapor inhalation (at the surface) exposures, while Tc-99 risk is primarily through groundwater ingestion and irrigating crops with groundwater. Simulated groundwater concentrations for the 1,000-year simulation period exceed MCLs immediately adjacent to the SDA for I-129, Tc-99, carbon tetrachloride, 1,4-dioxane, methylene chloride, nitrate, tetrachloroethylene, and trichloroethylene.

Figure 7-10 shows total risk over time and relative contributions attributable to each exposure pathway for the future residential scenario immediately adjacent to the SDA. Except for inhalation of volatiles, risk remains greater than 1E-05 for each exposure pathway throughout the 1,000-year simulation period, and cumulative risk remains well above 1E-03. External exposure and soil ingestion dominate the risk. Crop ingestion risk is initially higher than soil ingestion risk immediately after institutional control. Inhalation risk is less than 1E-05 immediately after institutional control but increases rapidly. Volatile inhalation risk is slightly greater than 1E-05 at the end of institutional control but decreases to less than 1E-05 within 50 years. Figures 7-11 through 7-15 illustrate individual pathway risks for surface exposure pathways over 1,000 years. Each figure shows the total by pathway, major contributors to the total, and the sum of other contaminants.

Figure 7-16 shows total 1,000-year groundwater ingestion risk for all radionuclides and nonradionuclides, major contributors to the total, and the sum of other contaminants. Groundwater ingestion risk immediately after the end of institutional control is driven by carbon tetrachloride and Tc-99. Within the 1,000-year simulation, eight contaminants exceed their respective MCLs: I-129, Tc-99, carbon tetrachloride, 1,4-dioxane, methylene chloride, nitrate, tetrachloroethylene, and trichloroethylene. Results for Tc-99 and I-129, particularly for groundwater exposure pathways, are highly uncertain because simulated concentrations in the vadose zone and aquifer are grossly inconsistent with monitoring data. As a consequence, groundwater risk attributable to these contaminants could be significantly misrepresented. For example, if actual release is very slow, initial risk (i.e., in the year 2110) would be substantially lower, perhaps less than 1E-05. Risk from slower release also would be incurred over a longer period. Conversely, the current simulations imply that risk is very high early in the simulation timeframe and diminishes over a few hundred years.

Groundwater simulations were extended to 10,000 years to evaluate long-lived radionuclides that did not achieve peak simulated concentrations in the 1,000-year simulations. Estimated risk is greater than or equal to 1E-05 for eight actinides: Ac-227, Np-237, Pa-231, U-233, U-234, U-235, U-236, and U-238. Primary contributors are Np-237 and U-238. Concentrations exceed MCLs in the 10,000-year simulations for these same two actinides.

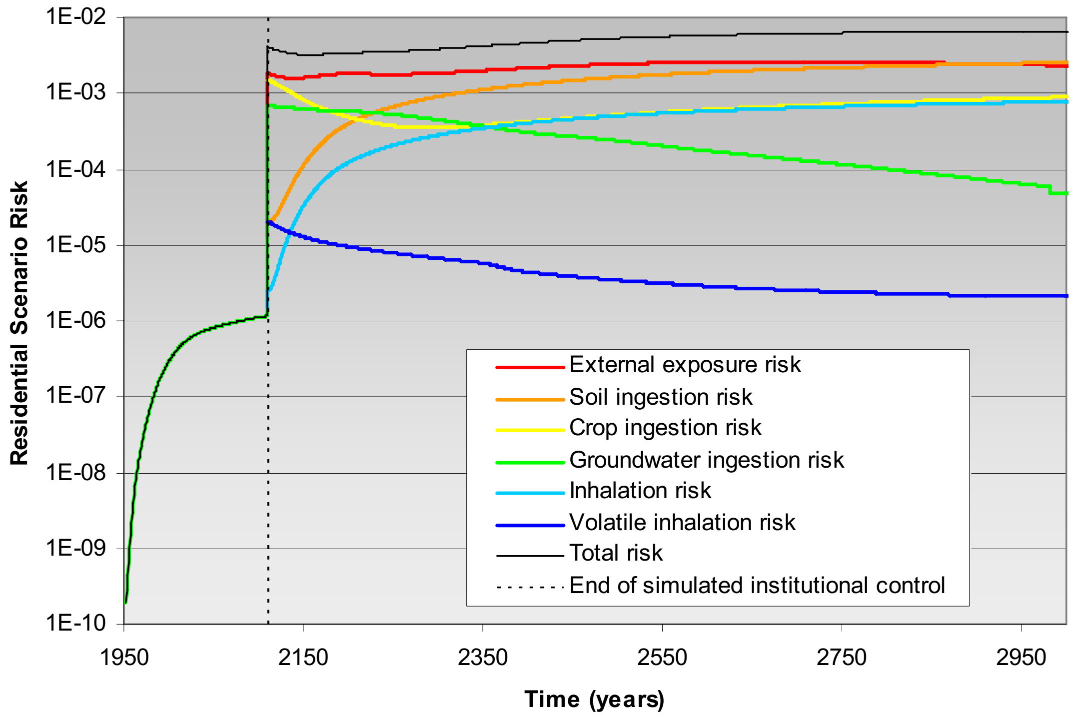


Figure 7-10. Total residential exposure scenario risk by exposure pathway for all radionuclides and nonradionuclides.

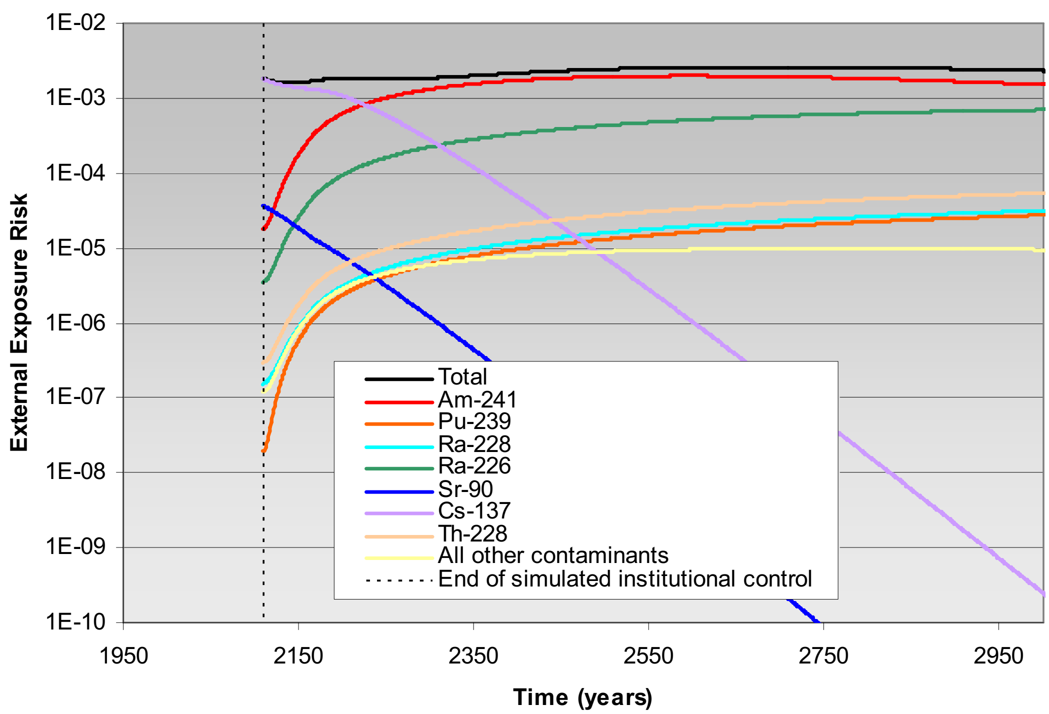


Figure 7-11. Major contributors to external exposure risk.

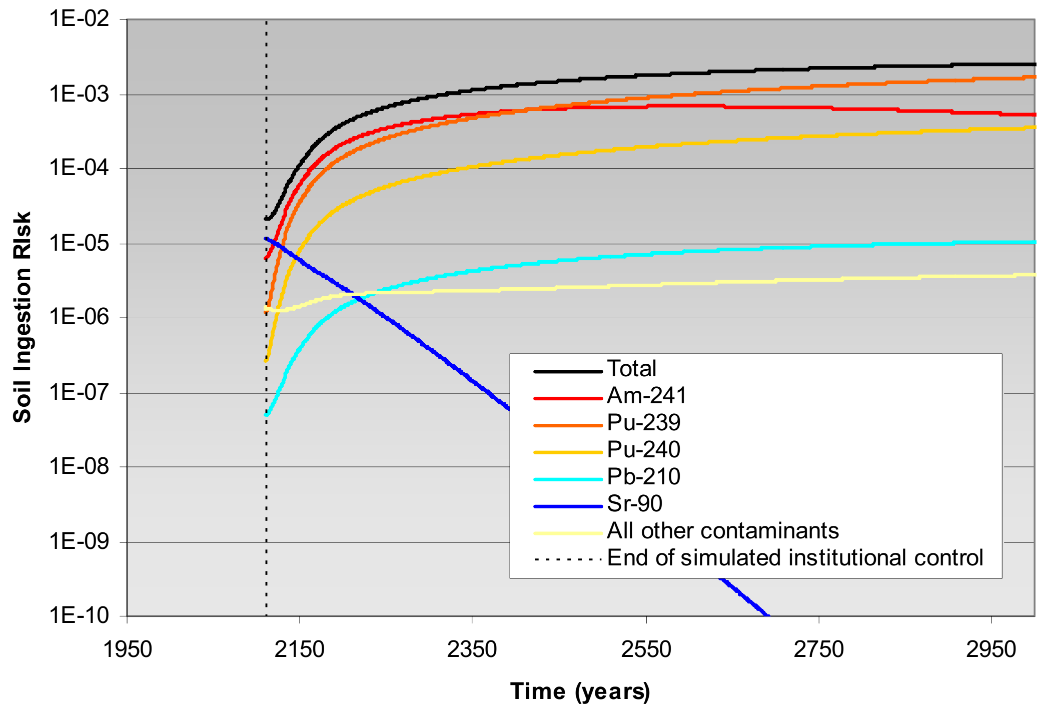


Figure 7-12. Major contributors to soil ingestion risk.

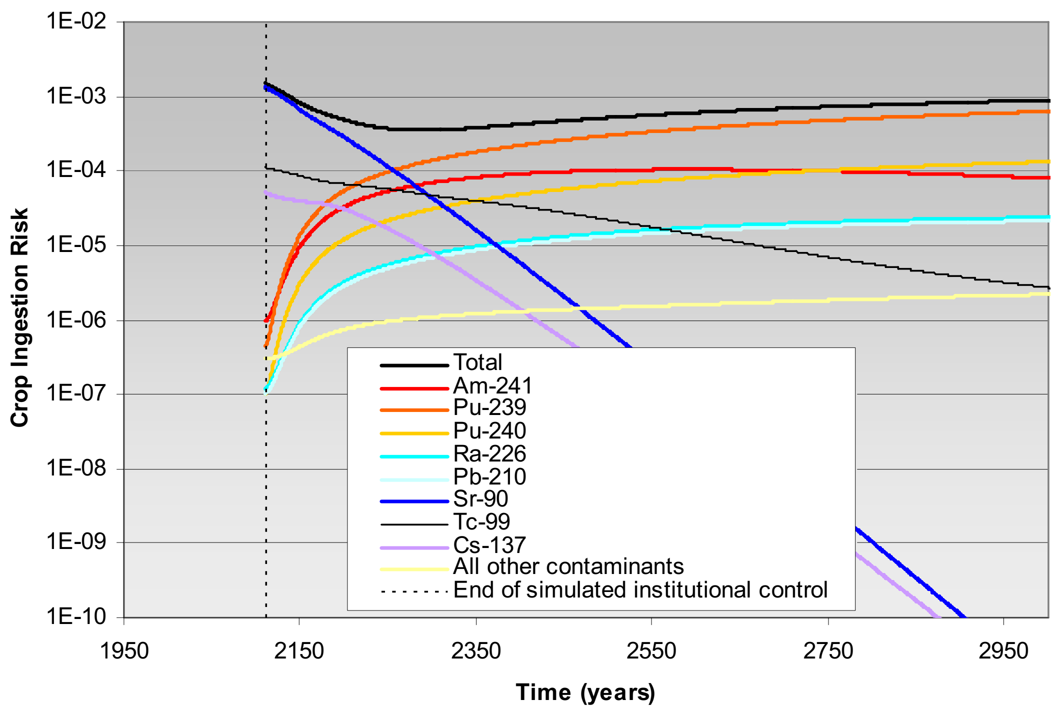


Figure 7-13. Major contributors to crop ingestion risk.

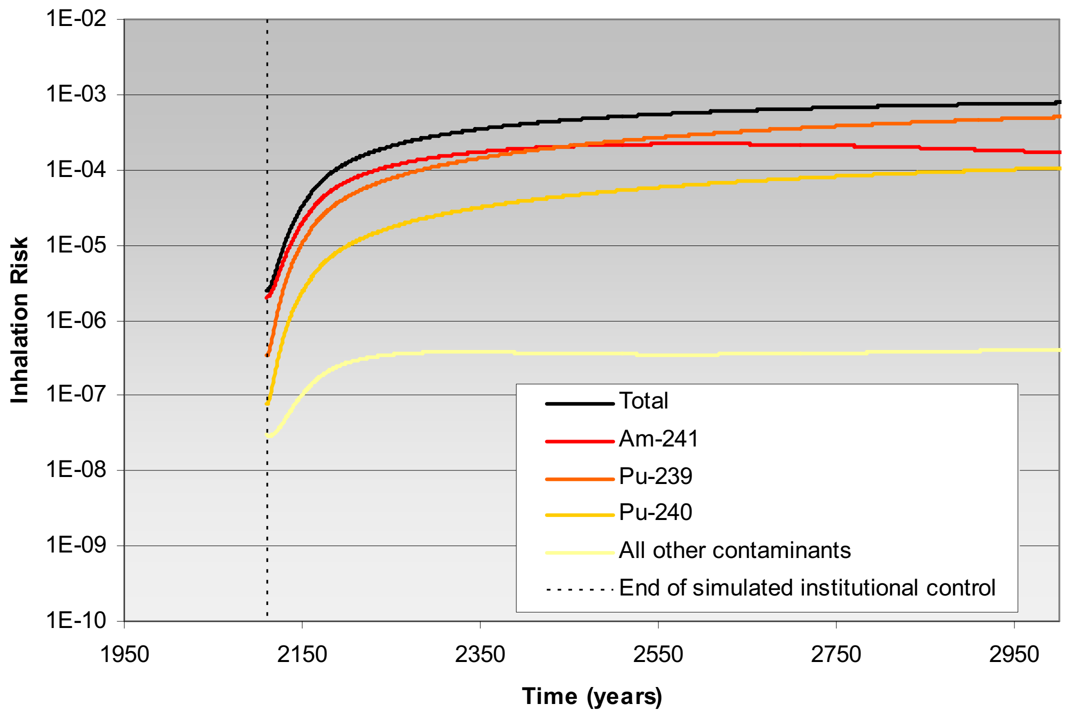


Figure 7-14. Major contributors to inhalation risk.

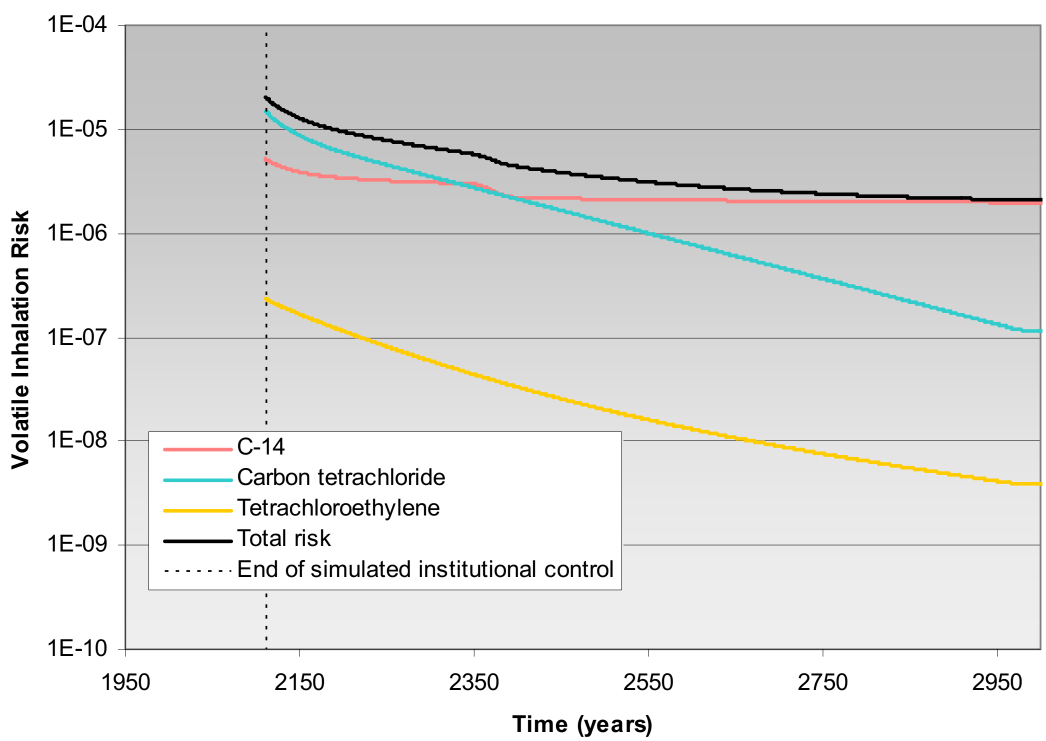


Figure 7-15. Volatile inhalation risk by contaminant.

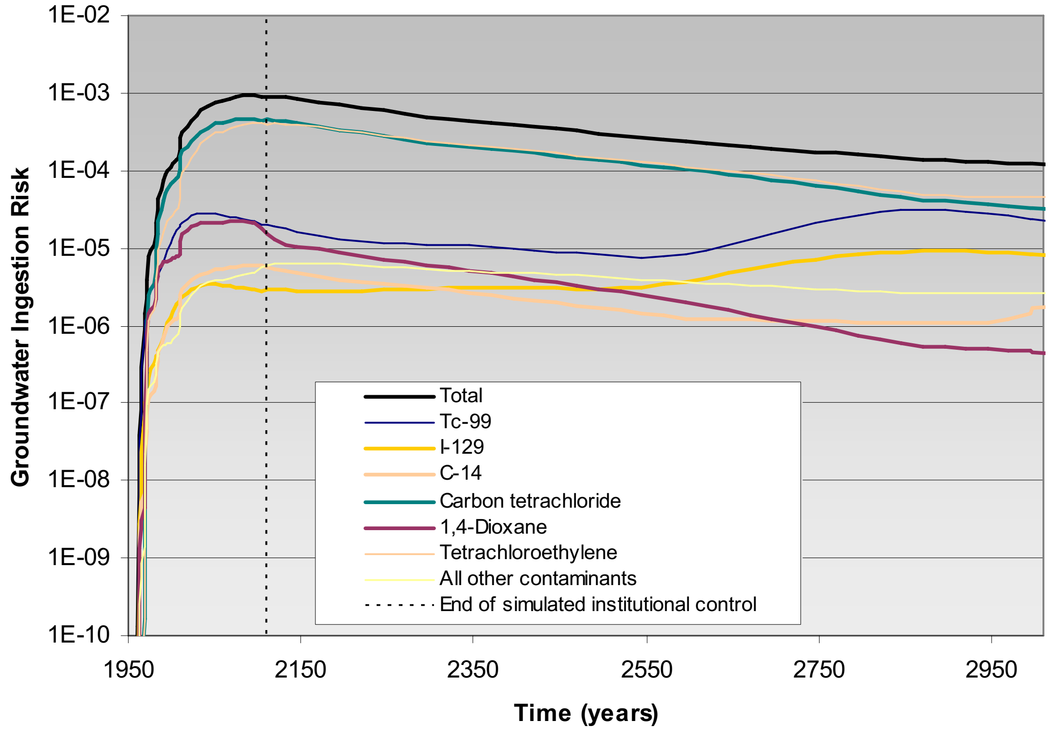


Figure 7-16. Groundwater ingestion risk by contaminant.

7.1.6.1.3 Uncertainty—Parametric sensitivity and qualitative uncertainty analyses were performed for parameters identified by DOE, DEQ, and EPA as important for understanding uncertainty in base-case risk. The sensitivity analysis shows the effect on predicted risk of changes in selected model inputs. With the exception of inventory sensitivity, sensitivity analysis focused on the groundwater ingestion pathway. The following list summarizes sensitivity cases:

- **Inventory**—To assess sensitivity to source-term inventory, risk was estimated based on upper-bound inventories. Risk estimates for most contaminants were of the same order of magnitude, with total cumulative risk for all contaminants higher by an approximate factor of 2.

- **Infiltration**—Three sensitivity cases addressing infiltration rates were examined: (1) reduced background infiltration outside the SDA, (2) low infiltration inside the SDA, and (3) high uniform infiltration inside the SDA. Reduced background infiltration produced slightly higher risk estimates, while lower and higher infiltration inside the SDA paralleled lower and higher risk.

- **Interbed gaps—**The effect of neglecting known gaps in the B-C interbed was evaluated by completely eliminating the B-C interbed in the model; negligible effect was noted.

- **Pit 4 retrieval and beryllium block grouting—**Because the base case incorporated assumptions that beryllium blocks would be grouted and targeted retrieval in Pit 4 would be completed, a sensitivity case was performed to examine consequences of not completing these remedial actions. If beryllium blocks are not grouted, C-14 groundwater ingestion risk increases slightly. If the half-acre retrieval in Pit 4 is not completed, groundwater risk does not change. Except for carbon tetrachloride, Rocky Flats Plant contaminants do not drive groundwater risk. The retrieval area contains only a small fraction of the carbon tetrachloride.

- **Low-permeability zone—**Effects of the postulated low-permeability zone assumed for the base case were evaluated by implementing a sensitivity case that did not include such a region in the aquifer. In the absence of a low-permeability zone, risk estimates are substantially lower (e.g., decrease from 3E-04 to 4E-05 for radionuclides, excluding Tc-99 and I-129), further suggesting that base-case model results are conservative.

- **No sorption in interbeds—**Removing the effects of plutonium sorption in interbed sediment was evaluated by completely eliminating sorption in the B-C and C-D interbeds using an approach roughly equivalent to spreading the plutonium source term into a thin layer (i.e., by advective spreading in the vadose zone) and leaching it directly into the aquifer. Results of this extremely conservative simulation show several orders of magnitude increase in risk.

7.1.6.2 Inadvertent Intruder Analysis. The intrusion scenario in Section 6.6 evaluates acute risk to a hypothetical worker drilling an agricultural irrigation well after the institutional control period. Two locations in the SDA (i.e., a high-gamma area and a high-alpha area) were selected for evaluation, based on disposal records. Results show that the high-gamma location could pose a risk of 4E-04, largely from external exposure to Cs-137. For the high-alpha location, the total risk is 4E-07.

7.1.6.3 Ecological Risk Assessment. The ecological risk assessment in Section 6.7 was a screening-level analysis because of the fundamental assumption that the SDA will be covered with a surface barrier (DOE-ID 1998; Holdren and Broomfield 2004). Current and 100-year scenarios were evaluated for representative receptors. Contaminant screening focused evaluation on those contaminants most likely to pose unacceptable risk; 56 contaminants of potential concern were identified—16 radionuclides and 40 nonradionuclides. Concentrations in surface soil and subsurface intervals were estimated with the DOSTOMAN biotic uptake model. Receptor exposures were evaluated for all 16 Waste Area Group 7 radionuclides; eight of the 40 nonradionuclides were evaluated as indicators of potential risk. Thirteen contaminants, ten radionuclides (i.e., Am-241, Cs-137, Pu-238, Pu-239, Pu-240, Pu-241, Ra-226, Sr-90, U-234, and U-238), and three nonradionuclides (i.e., beryllium, cadmium, and lead) were shown to pose risk greater than threshold values to Waste Area Group 7 ecological receptors in both the current and future scenarios.

7.2 Conclusions of the Remedial Investigation and Baseline Risk Assessment

Conclusions based on this RI/BRA provide the foundation for subsequent analysis and ultimately will support risk management decisions for Operable Unit 7-13/14. The first subsection below reviews the approach applied by DOE, DEQ, and EPA to address uncertainties inherent in this RI/BRA. Results of the risk assessment and uncertainty associated with those results then are used to transition from the RI/BRA to the feasibility study. Contaminants of *potential* concern (i.e., those contaminants that *might* pose unacceptable risk if no remediation is implemented) are screened to identify contaminants of concern (COCs) (i.e., those contaminants that might require risk management decisions). Final subsections present recommendations for the feasibility study and reiterate remedial action objectives.

7.2.1 Basis for Conclusions—Overall Uncertainty in Modeling and Risk Assessment

Personnel from DOE, DEQ, and EPA have actively participated throughout development of the RI/BRA to produce a mathematical modeling approach useful for predicting release and transport of contaminants from waste buried in the SDA. The unchanging goal has been to develop a reasonably conservative model—one that is not excessively conservative (overpredicting concentrations) or excessively nonconservative (underpredicting concentrations). This is a difficult goal to achieve in any simulation, but even more difficult for Operable Unit 7-13/14 for several reasons, as described in the following subsections.

7.2.1.1 Inventory. The SDA is a landfill that has received thousands of shipments over the past five decades. Thousands of records have been researched extensively to verify source-term information for the SDA. Data have been compiled into a database that can query shipments. Though some shipment locations have been verified through probing into a few key areas, absolute certainty is not a practical objective for a 97-acre landfill (containing approximately 35 acres of waste) that has been in service since 1952. However, the database includes inventory estimates (mass or curies), an approximate location, and waste form descriptions for almost every shipment placed in the SDA. This information is used to fulfill modeling requirements for site characterization data. For instance, modeling requires information about inventories of contaminants and the physical form of the waste. Information must be developed to address the following: whether contaminants are in solution, whether they are sorbed into a matrix in bags inside barrels, whether barrels are carbon steel or stainless steel, whether waste is in boxes and whether boxes are wood or cardboard, and how contaminants release from waste and how fast.

7.2.1.2 Infiltration. Movement of dissolved-phase (aqueous) contaminants in the unsaturated zone is controlled by the amount of water moving through the sedimentary layers. Typically, contaminants are transported in the shallow vadose zone in pulses that correlate with precipitation. These pulses are not specifically modeled. This compromise in the temporal effects of water movement causes some uncertainty in the modeling but was acceptable to DOE, DEQ, and EPA because pulses generally dampen with depth and do not influence long-term simulation results at depth. Water movement through sedimentary features can be described by a nonlinear set of equations, which are computer intensive to solve because the hydraulic conductivity of the layers depends on the moisture content and other characteristics of the materials in the layer. Complexity of variably saturated water movement through fractured basalts is less well understood, but significant insight into this movement and confidence in the equivalent-porous continuum modeling approach was gained by successful inverse modeling of a large-scale infiltration test that was conducted near RWMC in support of the RI/FS.

7.2.1.3 Sorption. Transport in the vadose zone and aquifer also is controlled by the tendency of each contaminant to adsorb onto sedimentary interbeds and, to a much lesser degree, to fractures in basalt. These contaminants can exist in different forms (e.g., oxidation states) in the environment, which greatly affects sorption. Mineralogy of sedimentary interbeds varies laterally and vertically within each sedimentary feature. An attempt to characterize spatial variability using distribution coefficients measured on corehole samples was unsuccessful in identifying spatial correlation. Therefore, single average values must be used to represent sorption for each contaminant, increasing the uncertainty in modeling results. Site-specific values were applied for sediments, when available; otherwise, conservative values were selected. Sorption of contaminants conservatively was assumed to not occur with fractured basalts.

7.2.1.4 Calibration. Modeling efforts at the other INL Site facilities (e.g., Test Area North and Idaho Nuclear Technology and Engineering Center) were facilitated by the presence of contaminants in soil, perched water, or the aquifer from past releases. Characterization data describing spatial and temporal aspects of these releases and presence of plumes within the aquifer provided benchmarks for model development. Fate and transport models could be reasonably calibrated to these plumes. A similar approach could not be implemented for Operable Unit 7-13/14 because well-defined plumes, patterns of detection, and consistent trends in concentrations do not exist, except for VOCs. Simulations for dissolved-phase contaminants, therefore, can be compared only to the absence or presence of contaminants in monitoring. The model sometimes predicts the presence of contaminants in the unsaturated zone or in the regional aquifer when those contaminants have not been detected. This modeling effort, except for calibrated VOC modeling, is wholly predictive.

7.2.1.5 Simulation Periods. Because this modeling effort is wholly predictive (except for VOCs), the predictive nature of the modeling for 100-year timeframes (i.e., restoration timeframe) is uncertain, and the degree of uncertainty is much greater for the longer 1,000-year timeframes. This uncertainty was recognized and accepted by DOE, DEQ, and EPA in the context of developing risk management decisions for Operable Unit 7-13/14. Extending groundwater simulations to 10,000 years was identified as necessary to assess potential long-term risk to human health and the environment because of the long-term presence and slow movement of some contaminants of concern. However, the level of uncertainty for these predictions is very large. These modeling predictions and the relative degree of uncertainty will be considered by DOE, DEQ, and EPA in developing risk management decisions.

7.2.2 Contaminants of Concern

Contaminants of concern are identified by reviewing human health risk estimates and simulated groundwater concentrations for contaminants of potential concern and applying screening criteria. Contaminants of concern are those individual contaminants that, when combined, cause cumulative risk to exceed threshold values. The EPA established a risk range from 10^{-4} to 10^{-6} for managing risk and expresses preference for the more protective end of the range (EPA 1991). The presence of multiple contaminants and exposure pathways (EPA 1989), land use projections (EPA 1995), and guidelines for risk management decisions (EPA 1997) also are important considerations in identifying COCs. Carcinogenic risk of 1E-04 and a hazard index of 1 for a future residential scenario are typical human health threshold values applied by DOE, DEQ, and EPA to support risk management decisions at the INL Site. Contaminants of concern then become the focus of an evaluation of remedial alternatives (i.e., a feasibility study) and, ultimately, risk management decisions.

Primary COCs for Operable Unit 7-13/14 are identified based on either of two screening criteria:

1. Contaminant has a total carcinogenic risk estimate greater than or equal to 1E-05 or a hazard index greater than or equal to 1 within the 1,000-year simulation period for the future residential exposure scenario. (The value of 1E-05 is used to identify COCs to ensure that additive carcinogenic risk from multiple contaminants remains less than the threshold of 1E-04.)

2. Simulated groundwater concentrations exceed the EPA MCLs within the 1,000-year simulation period.

Tables 7-1 and 7-2 identify radionuclide and nonradionuclide COCs, respectively, based on the above criteria. In total, 18 primary COCs are identified: 12 radionuclides and six nonradionuclides. Cumulative risk over time for all COCs is illustrated in Figure 7-10 for the future residential scenario. Total cumulative risk for all contaminants is at a maximum of 7E-03 at the end of the 1,000-year simulation period in the year 3010. Surface exposure pathways contribute the most risk throughout the 1,000-year simulation period, with a maximum of 7E-03. As shown in Figures 7-11 through 7-15, the most significant contributors to surface pathway risk are Am-241, Cs-137, Pu-239, Sr-90, and carbon tetrachloride.

Table 7-1. Primary radionuclide contaminants of concern based on 1,000-year future residential scenario peak risk estimates and groundwater concentrations.

Radionuclide	Peak Risk	Year	Primary Exposure Pathways[a]	Peak Aquifer Concentration (pCi/L)	Year	Maximum Contaminant Level (pCi/L)
Ac-227	5E-07	3010	Groundwater ingestion	5.30E-02	3010	15[b]
Am-241	3E-03	2594	External exposure, soil ingestion, inhalation, and crop ingestion	6.80E-08	3010	15[b]
Am-243	1E-07	3010	External exposure	1.29E-09	3010	15[b]
C-14	1E-05	2110	Groundwater ingestion and inhalation of volatiles (at the surface)	1.86E+02	2133	2,000
Cl-36	2E-06	2384	Groundwater ingestion and crop ingestion	2.12E+01	2395	700
Cs-137	2E-03	2110	External exposure and crop ingestion	NA	NA	NA
I-129	4E-05	2110	Groundwater ingestion	1.31E+01	2111[c]	1
Nb-94	2E-06	3010	External exposure	NA	NA	NA
Np-237	7E-06	2647	External exposure	6.53E-02	3010	15[b]
Pa-231	3E-07	3010	Groundwater ingestion	8.17E-02	3010	15[b]
Pb-210	3E-05	3010	Crop ingestion	1.02E-05	3010	NR
Pu-238	1E-06	2262	Soil ingestion, crop ingestion, and inhalation	6.10E-19	2920	15[b]
Pu-239	3E-03	3010	Soil ingestion, crop ingestion, and inhalation	5.19E-10	3010	15[b]
Pu-240	6E-04	3010	Soil ingestion, crop ingestion, and inhalation	1.28E-10	3010	15[b]
Ra-226	7E-04	3010	External exposure and crop ingestion	1.30E-05	3010	5
Ra-228	3E-05	3010	External exposure	1.97E-09	3010	5
Sr-90	1E-03	2110	Crop ingestion, external exposure, and soil ingestion	NA	NA	NA
Tc-99	3E-04	2110	Groundwater ingestion and crop ingestion (crops irrigated with contaminated groundwater)	2.71E+03	2111[c]	900
Th-228	5E-05	3010	External exposure	NA	NA	NA
Th-229	4E-07	3010	Groundwater ingestion	2.64E-02	3010	15[b]
Th-230	1E-08	3010	Crop ingestion, soil ingestion, and inhalation	3.01E-04	3010	15[b]
Th-232	3E-07	3010	Crop ingestion	2.82E-09	3010	15[b]
U-233	4E-06	3010	Groundwater ingestion	2.90E+00	3010	2.9E+05
U-234	6E-07	3010	Groundwater ingestion	3.97E-01	3010	1.87E+05
U-235	2E-07	2286	External exposure	1.19E-01	3010	6.49E+01
U-236	9E-07	3010	Groundwater ingestion	6.24E-01	3010	1.94E+03
U-238	1E-06	2285	External exposure	5.52E-01	3010	1.01E+01

a. All complete exposure pathways are assessed in the baseline risk assessment; those contributing most to risk are listed as primary exposure pathways. For COCs, all exposure pathways with risk greater than 1E-05 are listed from highest to lowest risk.
b. The limit is 15 pCi/L for total alpha (40 CFR 141).
c. Reported values are for the end of institutional control. The simulated peak occurs before the end of the 100-year institutional control period.
d. The limit is 3E-02 mg/L (30 µg/L) for total uranium. To compare concentrations of uranium isotopes, 3E-02 mg/L is converted to the equivalent activity for each isotope.

COC = contaminant of concern
MCL = maximum contaminant level
NR = not regulated

Surface exposure pathway COC	Groundwater pathway COC	COC for both surface exposure and groundwater pathways	COC based on potential to exceed MCL

Table 7-2. Nonradionuclide contaminants of concern based on 1,000-year future residential scenario peak risk estimates and groundwater concentrations.

Contaminant	Peak Risk	Year	Peak Hazard Index	Year	Primary Exposure Pathways[a]	Peak Aquifer Concentration (mg/L)[b]	Year	Maximum Contaminant Level (mg/L)
Carbon tetrachloride	5E-04	2110	1E+01	2116	Inhalation of volatiles (at the surface) and groundwater ingestion	3.07E-01	2133	5.00E-03
1,4-Dioxane	2E-05	2110	NA	NA	Groundwater ingestion	1.69E-01	2111	3.00E-03[b]
Methylene chloride	5E-06	2244	3E-02	2244	Groundwater ingestion	5.85E-02	2245	5.00E-03
Nitrate	NA	NA	1E+00	2110	Groundwater ingestion	6.67E+01	2094[c]	10
Tetrachloroethylene	7E-07	2110	3E-01	2133	Groundwater ingestion	6.64E-02	2145	5.00E-03
Trichloroethylene	9E-04[d]	2110	NA	NA	Inhalation of volatiles (at the surface) and groundwater ingestion	3.80E-02[d]	2130	5.00E-03

a. All complete exposure pathways are assessed in the baseline risk assessment; those contributing most to risk are listed as primary exposure pathways. For COCs all exposure pathways with risk greater than 1E-05 or a hazard index greater than or equal to 1 are listed from highest to lowest risk.
b. No MCL is given, but a health advisory level is provided for reference.
c. The simulated nitrate peak occurs before the end of the 100-year institutional control period.
d. Trichloroethylene risk estimates and groundwater concentrations are based on scaling. Refined estimates will be developed in the feasibility study.

COC = contaminant of concern
MCL = maximum contaminant level

Surface exposure pathway COC	Groundwater pathway COC	COC for both surface exposure and groundwater pathways	COC based on potential to exceed MCL

Cumulative groundwater ingestion risk within the 1,000-year simulation period reaches a peak of 7E-04 at the end of the simulated institutional control period, when the location for the hypothetical residential receptor shifts from the INL Site boundary to the SDA boundary. Groundwater ingestion risk steadily diminishes over the 1,000-year simulation period (see Figure 7-16). Cumulative groundwater ingestion risk isopleths are provided in Figures 7-17, 7-18, and 7-19 for the 1,000-year residential scenario. In addition, groundwater ingestion hazard indexes of 1E+01 and 1E+00 are associated with carbon tetrachloride and nitrate, respectively. Maximum hazard index isopleths are shown in Figure 7-20. Primary groundwater pathway risk drivers in the 1,000-year timeframe are carbon tetrachloride and Tc-99.

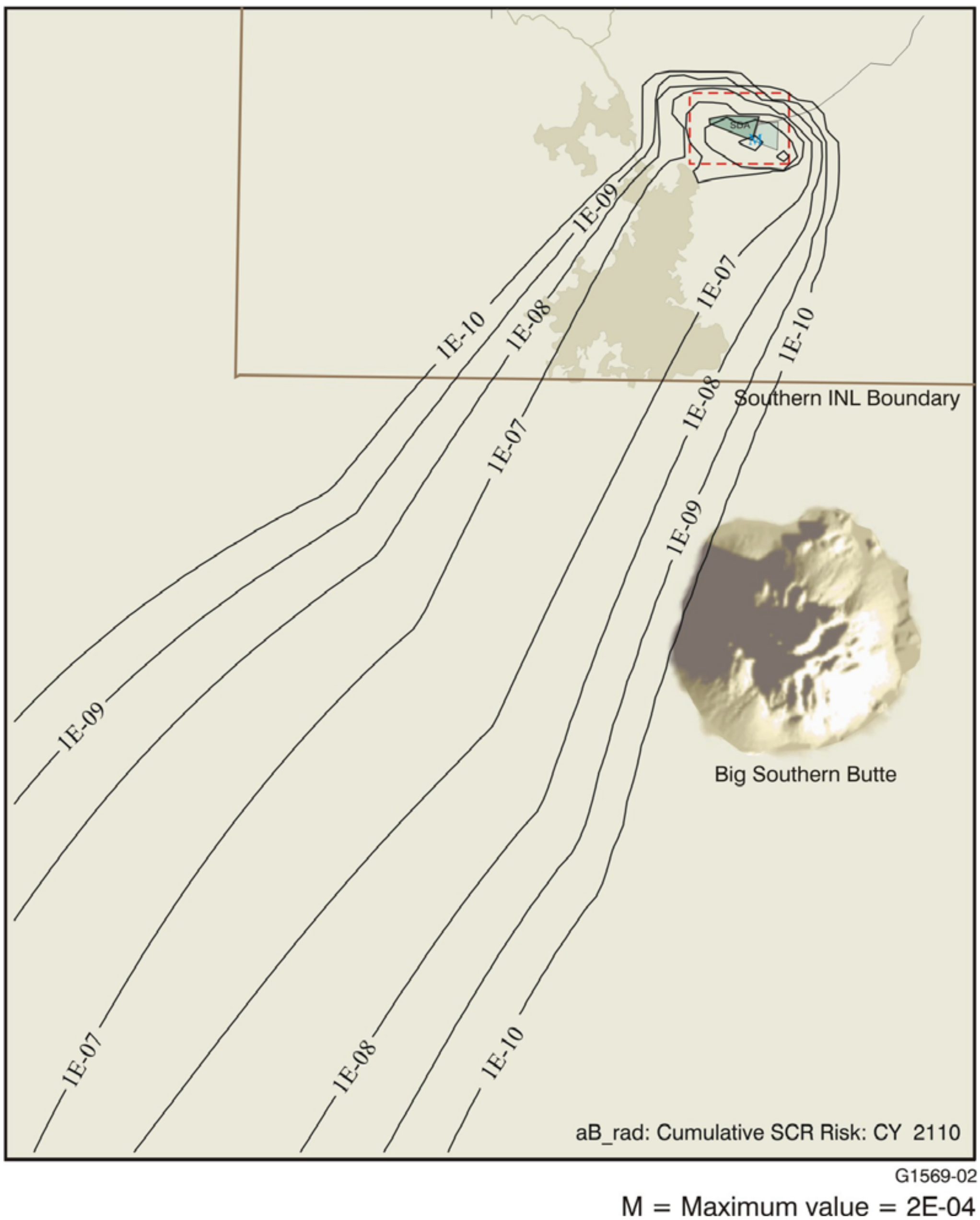
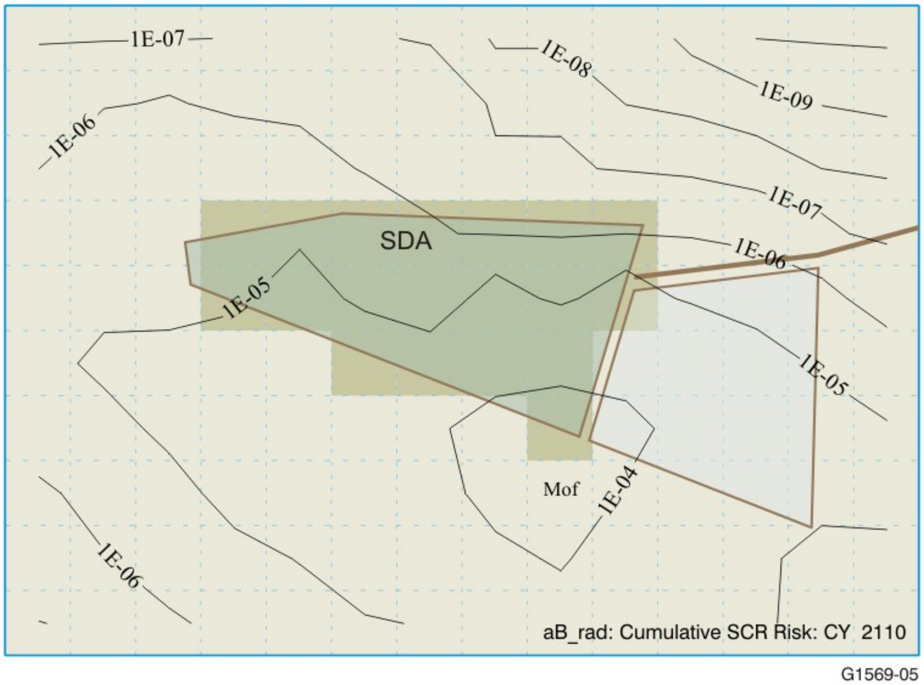
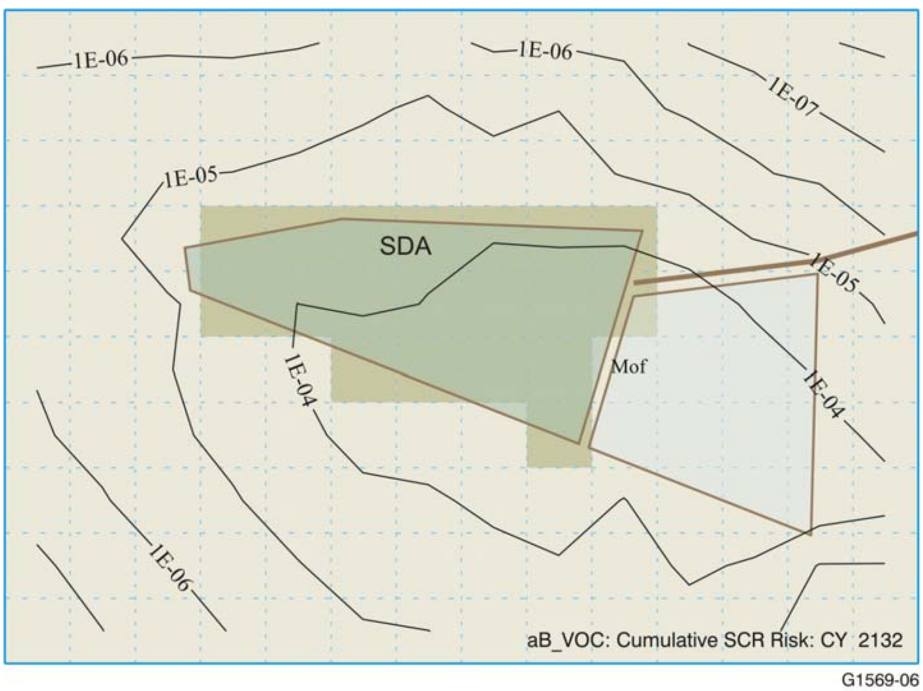


Figure 7-17. Peak cumulative groundwater ingestion risk isopleths for radionuclides for the regional refined grid.



Mof = Maximum value outside fence = 2E-04

Figure 7-18. Peak cumulative groundwater ingestion risk isopleths for radionuclides for the aquifer refined grid.



Mof = Maximum value outside fence = 5E-04

Figure 7-19. Peak cumulative groundwater ingestion risk isopleths for volatile organic compounds.

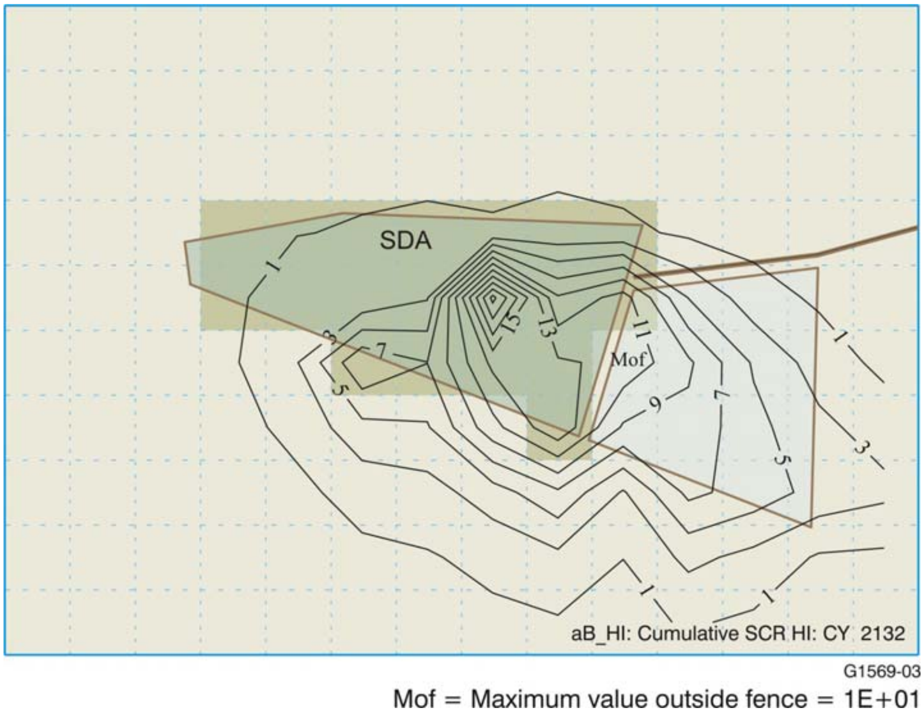


Figure 7-20. Peak cumulative groundwater ingestion hazard index isopleths.

Risk estimates for Tc-99 and I-129 are highly uncertain because of gross inconsistencies between simulated and detected concentrations. Risks for Tc-99 and I-129 are probably overestimated, perhaps substantially. Figure 7-21 shows groundwater ingestion risk with and without Tc-99 and I-129, illustrating upper-bound (represented by overestimated base case results) and lower-bound groundwater ingestion risk (represented by completely excluding Tc-99 and I-129). Actual risk is somewhere between these two extremes for Tc-99 and I-129. For comparison to Figure 7-18, Figure 7-22 shows groundwater risk isopleths without Tc-99 and I-129.

Simulated groundwater concentrations exceed MCLs (EPA 2000) within the 1,000-year simulation period for eight contaminants: two radionuclides and six nonradionuclides. Both radionuclides (i.e., I-129 and Tc-99) and four of the nonradionuclides (i.e., carbon tetrachloride, 1,4-dioxane, nitrate, and trichloroethylene) are identified as COCs because they exceed risk thresholds. Two additional COCs (i.e., methylene chloride and tetrachloroethylene) are identified solely on their potential to exceed their respective MCLs.

In total, 18 primary COCs are identified based on human health risk estimates or potential to exceed MCLs in the aquifer. Table 7-3 identifies waste streams associated with these primary COCs. Several COCs (i.e., Pb-210, Ra-226, Ra-228, and Th-228) have very small initial inventories generated at the INL Site; however, risk is driven by inventories generated through ingrowth attributable to Rocky Flats Plant waste streams.

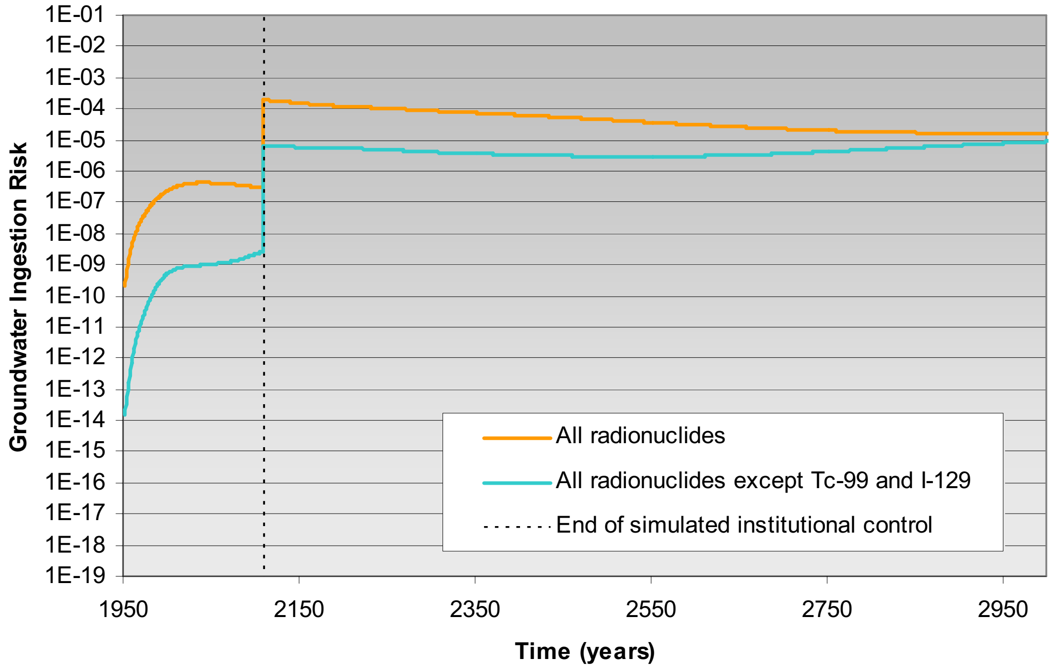


Figure 7-21. Groundwater ingestion risk for radionuclides, including and excluding technetium-99 and iodine-129.

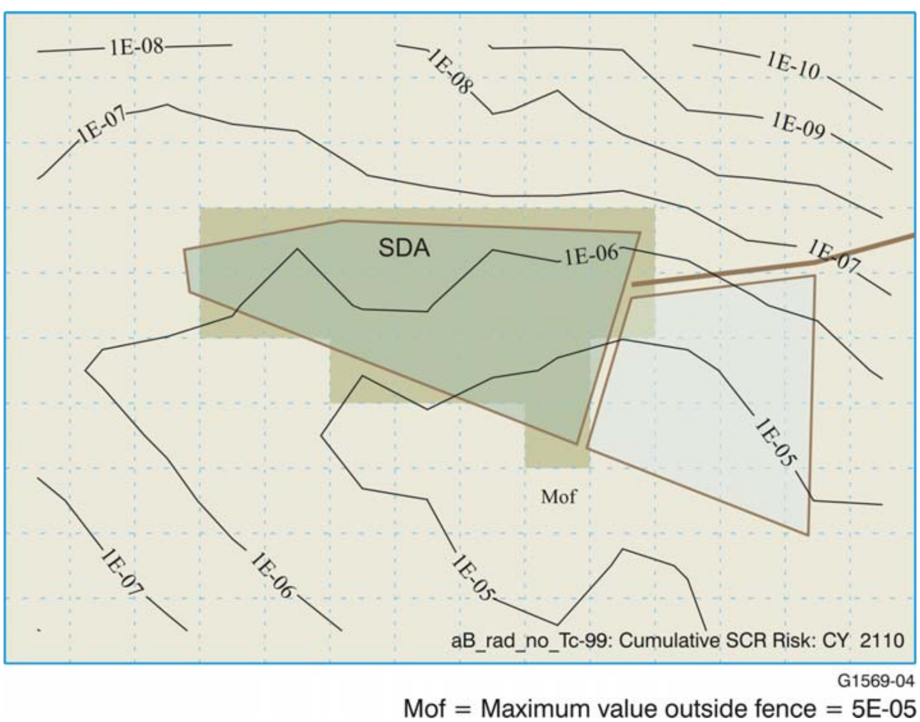


Figure 7-22. Peak cumulative groundwater ingestion risk isopleths for radionuclides, excluding technetium-99, for comparison to Figure 7-18.

Table 7-3. Original waste generators and general locations of primary contaminants of concern in the Subsurface Disposal Area.

Contaminant	Waste Generator[a]	Portion (%)	Initial Inventory[b]	Areas of Highest Densities
Am-241	Rocky Flats Plant	100.0	2.43E+05	Pits
C-14	INL Site	100.0	7.31E+02	Trenches and soil vaults
Cs-137	INL Site	100.0	1.68E+05	Trenches and soil vaults
I-129	INL Site	100.0	1.88E-01	Trenches and soil vaults
Pb-210	Rocky Flats Plant	NA[c]	NA[c]	Pits
Pb-210	INL Site	100.0[c]	5.62E-07[c]	Trenches
Pu-238[d]	Rocky Flats Plant	88.7	1.85E+03	Pits
Pu-238[d]	INL Site	11.3	2.35E+02	Trenches
Pu-239	Rocky Flats Plant	98.3	6.30E+04	Pits
Pu-239	INL Site	1.7	1.08E+03	Trenches
Pu-240	Rocky Flats Plant	96.6	1.40E+04	Pits
Pu-240	INL Site	3.4	5.03E+02	Trenches
Ra-226	Rocky Flats Plant	NA[e]	NA[e]	Pits
Ra-226	INL Site	100.0[e]	6.53E+01[e]	Trenches
Ra-228	Rocky Flats Plant	NA[f]	NA[f]	Pits
Ra-228	INL Site	100.0[f]	3.66E-05[f]	Trenches
Sr-90	INL Site	100.0	1.36E+05	Trenches and soil vaults
Tc-99	INL Site	100.0	4.23E+01	Trenches and soil vaults
Th-228	Rocky Flats Plant	NA[g]	NA[g]	Pits
Th-228	INL Site	100.0[g]	1.05E+01[g]	Low-Level Waste Pit
Carbon tetrachloride	Rocky Flats Plant	100.0	7.90E+08	Pits
1,4-Dioxane	Rocky Flats Plant	96.0	1.87E+06	Pits (with carbon tetrachloride)
1,4-Dioxane	INL Site	4.0	4.24E+04	Pits, trenches, and soil vaults
Methylene chloride	Rocky Flats Plant	100.0	1.41E+07	Pits
Nitrate (as nitrogen)	Rocky Flats Plant	89.1	4.06E+08	Pits and Pad A
Nitrate (as nitrogen)	INL Site	10.9	4.98E+07	Pits
Tetrachloroethylene	Rocky Flats Plant	100.0	9.87E+07	Pits (with carbon tetrachloride)
Trichloroethylene	Rocky Flats Plant	99.6	8.92E+07	Pits (with carbon tetrachloride)
Trichloroethylene	INL Site	0.4	4.07E+05	Trenches

a. Portions listed for INL Site waste may include small amounts from off-INL Site waste generators, excluding Rocky Flats Plant.
b. Initial inventory at time of disposal; units are curies for radionuclides and grams for nonradionuclides.
c. Risk is attributable to ingrowth of Pb-210 from Pu-238 and U-238; initial disposal quantities are not significant.
d. Pu-238 is not, itself, a COC. However, Pu-238 decays to two COCs (i.e., Pb-210 and Ra-226).
e. Risk is attributable to ingrowth of Ra-226 from Pu-238 and U-238; initial disposal quantities are not significant.
f. Risk is attributable to ingrowth of Ra-228; initial disposal quantities are not significant. Ingrowth is primarily associated with Pu-240 from Rocky Flats Plant.
g. Risk is attributable to ingrowth of Th-228; initial disposal quantities are not significant. Ingrowth is primarily associated with Pu-240 from Rocky Flats Plant, though a small portion arises and then decays from U-232.

INL = Idaho National Laboratory

To address uncertainties associated with model results, simulations were extended to 10,000 years for long-lived radionuclides that did not reach peak simulated concentrations in 1,000-year simulations. Residential scenario risk estimates are greater than 1E-05 in the 10,000-year simulation period for eight radionuclides: Ac-227, Np-237, Pa-231, U-233, U-234, U-235, U-236, and U-238. These eight radionuclides are identified as secondary COCs for the Operable Unit 7-13/14 feasibility study. Table 7-4 lists secondary COCs. Figure 7-23 shows groundwater ingestion risk for all eight radionuclides. Figures 7-24 and 7-25 show peak groundwater risk isopleths at the end of the 10,000-year simulation period for regional and local scales.

Table 7-4. Secondary radionuclide contaminants of concern based on 10,000-year future residential scenario groundwater ingestion peak risk estimates and groundwater concentrations.

Radionuclide	Peak Risk	Calendar Year	Peak Aquifer Concentration	Maximum Contaminant Level
Ac-227	2E-05	12000	2.31E+00 pCi/L	15 pCi/L[a]
Np-237	1E-04	12000	8.68E+01 pCi/L	15 pCi/L[a]
Pa-231	1E-05	12000	3.20E+00 pCi/L	15 pCi/L[a]
U-233	2E-05	5352	1.30E+01 pCi/L	2.9E+05 pCi/L[b]
U-234	4E-05	12000	2.71E+01 pCi/L	1.87E+05 pCi/L[b]
U-235	1E-05	12000	7.18E+00 pCi/L	6.49E+01 pCi/L[b]
U-236	1E-05	12000	8.29E+00 pCi/L	1.94E+03 pCi/L[b]
U-238	9E-05	12000	4.71E+01 pCi/L	1.01E+01 pCi/L[b]
Total uranium[c]	NA	12000	1.44E-01 mg/L[c]	3.00E-02 mg/L[c]

a. The limit is 15 pCi/L for total alpha (40 CFR 141).
b. The limit is 3E-02 mg/L (30 µg/L) for total uranium. To compare concentrations of uranium isotopes, 3E-02 mg/L is converted to the equivalent activity for each isotope.
c. Total uranium is presented only for assessing simulated concentrations against the maximum contaminant limit. The peak concentration for total uranium is given in mg/L, developed by converting activity for each uranium isotope to mass and summing the results regardless of the timing of the peak. The maximum contaminant level is exceeded for total uranium, which is attributable almost completely to U-238.

Secondary contaminant of concern based on 10,000-year risk or concentration

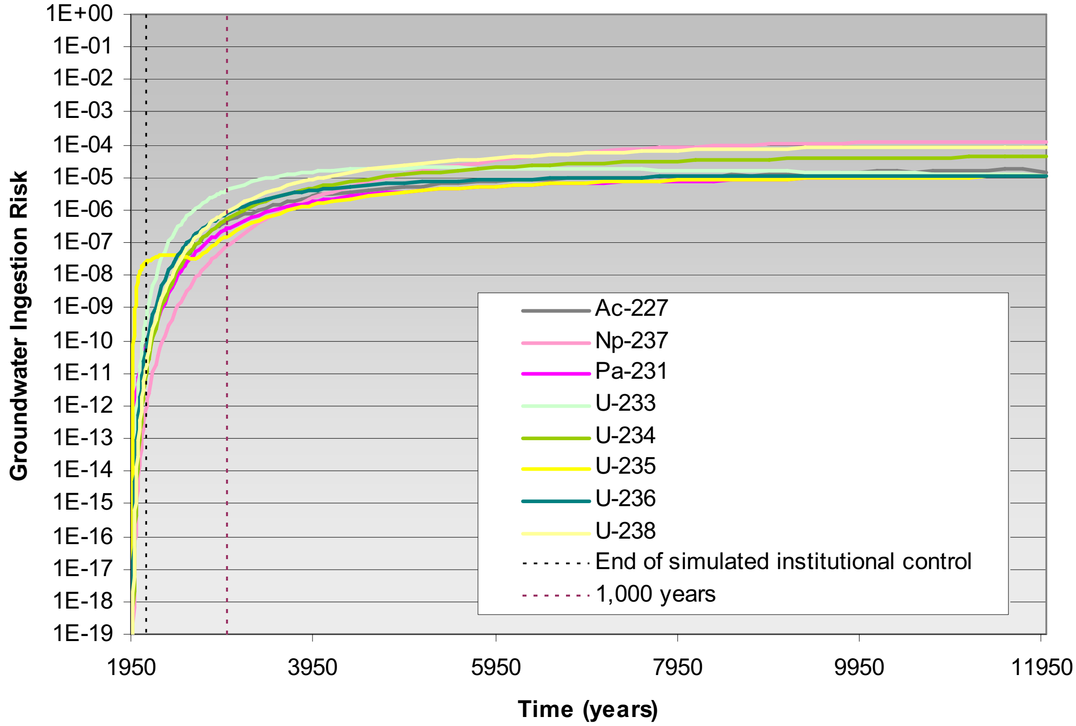


Figure 7-23. Simulated 10,000-year groundwater ingestion risk for contaminants that peak after 1,000 years.

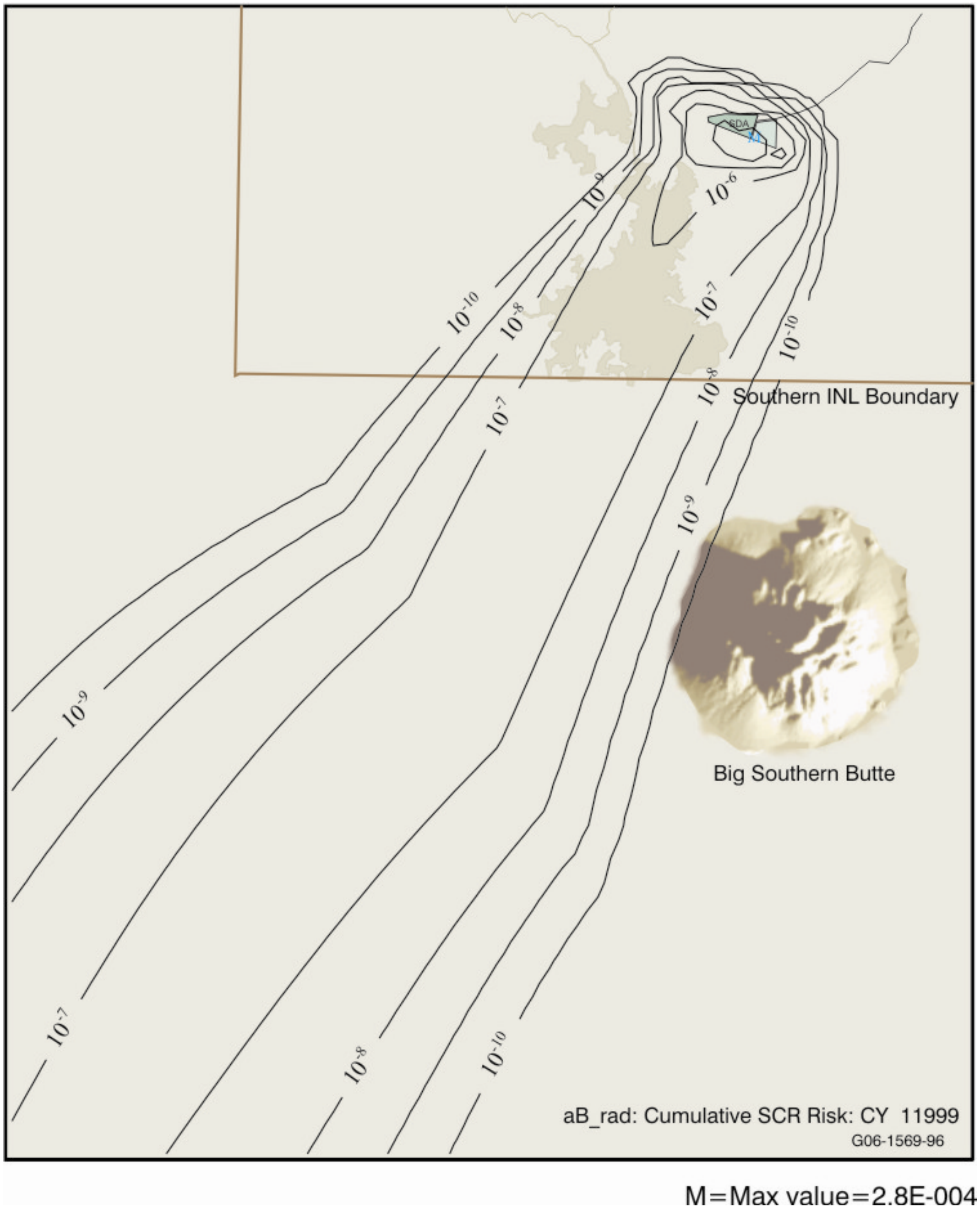


Figure 7-24. Peak groundwater risk isopleths for radionuclides at the end of the 10,000-year groundwater simulation period for the regional refined grid.

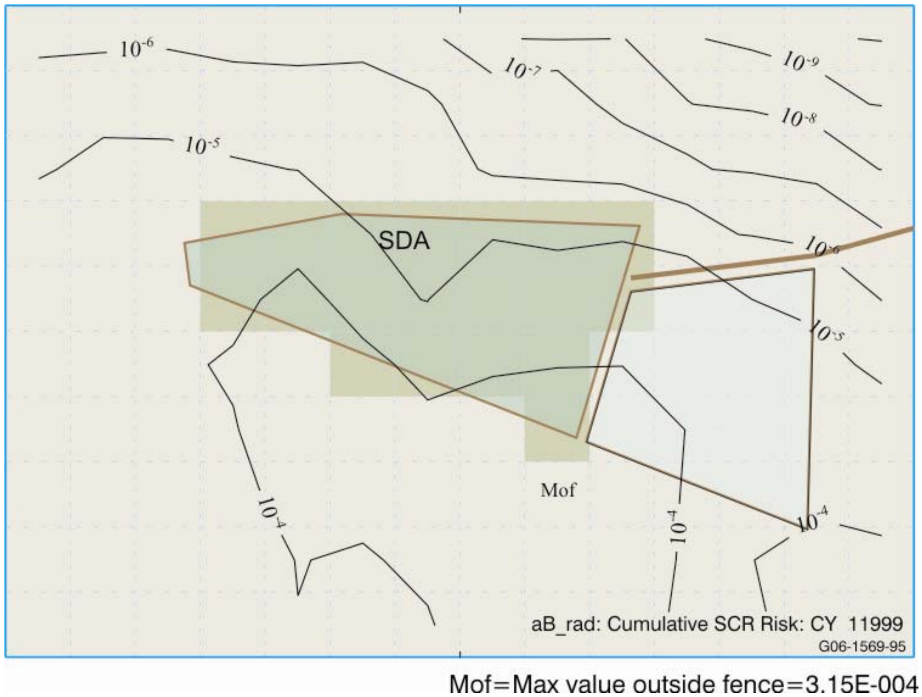


Figure 7-25. Peak cumulative groundwater risk isopleths for radionuclides at the end of the 10,000-year groundwater simulation period for the local refined grid.

7.2.3 Bases for the Feasibility Study

According to an assumption in the Second Addendum (Holdren and Broomfield 2004) remedial action will be implemented for Operable Unit 7-13/14 if risk estimates exceed threshold values or simulated aquifer concentrations exceed MCLs. As demonstrated by the modeling and baseline risk assessment presented in this RI/BRA, these conditions are identified; therefore, a feasibility study will be prepared to evaluate remedial alternatives. The Operable Unit 7-13/14 feasibility study should focus on remedial alternatives that address the primary COCs identified in Tables 7-1 and 7-2.

Source-term information developed through records research, geophysical surveys, inventory reconstruction, and mapping have proven reliable through probing and retrieval demonstrations. This information, in conjunction with risk estimates, provides a good foundation for the feasibility study. As described in Table 7-3, high densities of fission- and activation-product COCs generated through reactor operations at the INL Site (i.e., C-14, Tc-99, I-129, and Sr-90) are located primarily in trenches and soil vaults. Conversely, Rocky Flats Plant-generated COCs—VOCs, nitrate, and actinides including Am-241, plutonium isotopes, and their long-lived progeny (i.e., Ra-226, Ra-228, and Pb-210)—are located mostly in pits. Roughly half of the total nitrate in the SDA is located on Pad A. Both INL Site- and Rocky Flats Plant-generated COCs contribute to surface exposure pathway risk. Groundwater pathway primary COCs include VOCs and nitrate, which originated at the Rocky Flats Plant, and Tc-99 and I-129, which originated at the INL Site. Secondary groundwater pathway COCs are long-lived decay-chain actinides associated with Rocky Flats Plant waste: Ac-227, Np-237, Pa-231, U-233, U-234, U-235, U-236, and U-238. Most of the waste producing these decay-chain progeny is located in pits, though a sizable fraction of uranium-related waste is on Pad A.

Preliminary remediation goals should be defined for primary COCs. Goals for surface exposure pathways should be predicated on reducing exposure-point concentrations (e.g., concentrations in soil and air) to protective levels. Remediation goals for the groundwater pathway should be based, at least in part, on anticipated performance of the surface barrier. The surface barrier is an element of final remediation for Operable Unit 7-13/14 because DOE, DEQ, and EPA recognize the impracticality of returning the SDA to a pristine state. A surface barrier is required to address contamination remaining at the site in two ways: (1) limiting infiltration and consequent transport downward through the vadose zone and aquifer and (2) inhibiting transport upward to the surface by plants and burrowing animals.

Simulations showing gross overpredictions (up to three orders of magnitude) of vadose zone and aquifer concentrations for Tc-99 and I-129 (see Section 5.2.5) should be refined before preliminary remediation goals are established for the feasibility study. These contaminants are modeled as highly mobile (i.e., with a distribution coefficient of 0 mL/g), which is based on current literature; however, monitoring data clearly refute rapid release from the source. Rather than assuming that these contaminants are available for immediate release through surface washoff, slower release through distributed container failure should be evaluated. Initial research indicates that many waste forms containing Tc-99 and I-129 were buried in welded stainless steel containers. If sufficient information can be collected to support a new model run for the feasibility study, a revised feasibility study baseline should be developed for Tc-99 and I-129.

Modeling and risk assessment for trichloroethylene should be refined early in development of the feasibility study to confirm that trichloroethylene is a COC and to provide a better basis for defining preliminary remediation goals. Trichloroethylene was semiquantitatively evaluated in the RI/BRA by scaling its inventory against carbon tetrachloride to estimate risk. Trichloroethylene is an organic solvent contained primarily in Rocky Flats Plant Series 743 sludge and is largely collocated with carbon tetrachloride.

Secondary COCs are defined based on the 10,000-year simulation period. Secondary COCs should not be direct targets for focused analysis of alternatives in the feasibility study (e.g., no preliminary remediation goals or additional grout case for actinides), but the long-term effectiveness of all assembled alternatives for these COCs should be evaluated and presented in the feasibility study. The feasibility study should include a sensitivity case to show that grouting would not effectively address secondary COCs in the far future. In addition, the feasibility study should evaluate the effectiveness of a surface barrier (assumed to be effective indefinitely) and retrieval (which is scalable to any size for targeted waste forms) in reducing long-term risk for these secondary COCs. Secondary COCs also should be identified as analytes for environmental monitoring to expedite periodic review of their status and to ensure that remedies are protective.

7.2.4 Remedial Action Objectives

As indicated in the Second Addendum (Holdren and Broomfield 2004), the feasibility study will be based on the assumption that source-term control will sufficiently reduce risk. Methods to mitigate contaminants that have already been released will not be evaluated in the Operable Unit 7-13/14 feasibility study, except to address continued operation of the vapor vacuum extraction system. Based on this assumption, remedial action objectives for Operable Unit 7-13/14 are provided in the Second Addendum and remain appropriate for developing the feasibility study. The only modifications are to replace the ABRA with this RI/BRA as the basis and to reduce the cumulative hazard index from 2 to 1. The first two remedial action objectives are related to risk thresholds. The last three objectives express the fundamental assumption that remedial action at the SDA will include an engineered surface barrier. Remedial action objectives are:

- Limit cumulative human health cancer risk for all exposure pathways to less than or equal to 1E-04

- Limit noncancer risk for all exposure pathways to a cumulative hazard index of less than 1 for current and future workers and future residents

- Inhibit migration of COCs, as identified in the RI/BRA, into the vadose zone and the underlying aquifer

- Inhibit exposures of ecological receptors to COCs in soil and waste with concentrations greater than or equal to 10 times background values and with a hazard quotient greater than or equal to 10

- Inhibit transport of COCs to the surface by plants and animals.

7.3 References

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